DEFENCE RESEARCH ESTABLISHMENT
CENTRE DE RECHERCHES POUR LA DÉFENSE
VALCARTIER, QUÉBEC

DREV - TM-9739

Unlimited Distribution/Distribution illimitée

# THE REFORMULATION OF THE FAMILY OF CRITERIA IN COMMANDER'S EXPERT SYSTEM ADVISOR (CESA)

by

I. Abi-Zeid, M. Bélanger, A. Guitouni*, and J.-M. Martel*

June/juin 1998

RESEARCH AND DEVELOPMENT BRANCH
DEPARTMENT OF NATIONAL DEFENCE
CANADA
BUREAU - RECHERCHE ET DÉVELOPPEMENT
MINISTÈRE DE LA DÉFENSE NATIONALE

105-01839/

DEFENCE RESEARCH ESTABLISHMENT
CENTRE DE RECHERCHES POUR LA DÉFENSE
VALCARTIER

DREV - TM-9739
Unlimited Distribution/Distribution illimitée

# THE REFORMULATION OF THE FAMILY OF CRITERIA IN COMMANDER'S EXPERT SYSTEM ADVISOR (CESA)

by
I. Abi-Zeid, M. Bélanger, A. Guitouni*, and J.-M. Martel*

June/juin 1998

* Université Laval, Ste-Foy, Québec

Approved by/approuvé par

Gaétan Picard

Section Head/Chef de section

2/6/98

Date

**WARNING NOTICE**

The information contained herein is proprietary to Her Majesty and is provided to the recipient on the understanding that it will be used for information and evaluation purposes only. Any commercial use, including use for manufacture, is prohibited. Release to third parties of this publication or of information contained herein is prohibited without the prior written consent of DND Canada.

© Her Majesty the Queen in Right of Canada as represented by the Minister of National Defence, 1998

**ABSTRACT**

This memorandum presents a brief description of the current state of an advisor tool developed at DREV for the Air Commander, called Commander's Expert System Advisor (CESA). CESA takes a list of courses of actions (COAs) constructed in response to an event, evaluates them with respect to certain factors and subfactors, obtains a ranking of these COAs using priorities given by the Commander, and then recommends a COA.

The main goal of this work is to report the results of a research project which redefined the factors and subfactors in CESA as 14 criteria in a multicriteria decision aid context. Many subfactors were eliminated, and new scales for evaluating the COAs were developed. This reformulation of the criteria is specific to events that correspond to the violation of Canadian airspace in a counterdrug scenario in a peace time normal context.

**RÉSUMÉ**

Ce mémorandum présente une brève description d'un outil d'aide à la décision développé au CRDV et destiné au commandant de l'air: "Commander's Expert System Advisor" (CESA). CESA est un outil qui évalue, par rapport à des facteurs et des sous-facteurs, des suites d'actions élaborées en réponse à un événement. Il utilise ensuite les priorités spécifiées par le commandant afin d'obtenir un rangement de ces suites d'actions et de faire des recommandations.

Le but de ce travail est de décrire les résultats d'un projet de recherche dans lequel les facteurs et les sous-facteurs de CESA ont été reformulés comme 14 critères dans un contexte d'aide à la décision multicritère. On a éliminé plusieurs facteurs et proposé de nouvelles échelles pour évaluer les suites d'actions. La reformulation des critères est propre aux événements correspondant à la violation de l'espace aérien canadien dans un scénario de contrebande de drogue en temps de paix normal.

## TABLE OF CONTENTS

ABSTRACT/RÉSUMÉ ..... i

EXECUTIVE SUMMARY ..... v

1.0 INTRODUCTION ..... 1

2.0 COMMANDER'S EXPERT SYSTEM ADVISOR (CESA) ..... 2

2.1 Events ..... 2

2.2 Courses of Action ..... 2

2.3 Options ..... 3

2.4 Factors and Subfactors ..... 3

2.5 Prioritization Weights ..... 5

2.6 Evaluation of a COA ..... 5

3.0 RESULTS OF THE CRITERIA REFORMULATION ..... 7

3.1 Desirable Theoretical Properties ..... 7

3.2 Weaknesses of the Present Formulation in CESA ..... 8

3.3 The Reformulated Family of Criteria: Results ..... 9

4.0 CONCLUSIONS ..... 24

5.0 REFERENCES ..... 25

APPENDIX A - Event Conditions Parameters ..... 26

APPENDIX B - Action Items Parameteres.....33

APPENDIX C - COA Features.....35

APPENDIX D - Factors and Subfactors.....78

APPENDIX E - Prioritization Weights.....82

APPENDIX F - Evaluation of a COA.....83

TABLES I to V

FIGURES 1 to 8

## EXECUTIVE SUMMARY

In a Canadian airspace violation situation, the Executive Element (the Battle Commander and his senior staff) must elaborate and evaluate different courses of action (COA) in order to choose the most appropriate one. Since they have to deal with a large volume of information within a very short time period, they need decision support systems to help them in the generation and the evaluation of the COAs.

DREV has been working on developing an advisor tool to assist the Commander in the evaluation, ranking, and selection of COAs. A first prototype called CESA (Commander's Expert System Advisor) was developed and demonstrated. However, further work is needed in order to improve this tool's theoretical basis. This pertains specifically to the definition of the criteria and of their evaluation scales as well as to the aggregation procedure used to assign a global score to each COA.

A new family of 14 criteria for the counterdrug scenario in a peace time normal context have been reformulated and their scales were redefined. This was done in order to ensure that the family of criteria possess the necessary theoretical properties, which would guarantee the robustness of the decisions based on CESA.

The investigation of multicriteria methods conducted in this project has allowed to develop a new family of criteria for the evaluation of COAs. This will lead to the development of an operational COA advisor for the management and employment of air defence resources for the protection of Canadian airspace.

# 1.0 INTRODUCTION

In response to a Canadian Airspace violation, the Air Commander must take a decision on the course of action (COA) to follow. He usually selects such a COA from a set of possible COAs elaborated by his staff.

DREV has been working on developing an advisor tool to assist the Commander in the evaluation, ranking, and selection of COAs. A first prototype called CESA (Commander's Expert System Advisor) was developed and demonstrated (Ref. 1). However, further work is needed in order to improve this tool's theoretical basis. This pertains specifically to the definition of the criteria and of their evaluation scales as well as to the aggregation procedure used to assign a global score to each COA.

The goal of this document is to present the new family of 14 criteria for the counterdrug scenario in a peace time normal context which have been reformulated and which scales were redefined. This was done in order to ensure that the family of criteria possess the necessary theoretical properties, which increases the robustness of the decisions based on CESA.

The current configuration of CESA is described in Chapter 2. Chapter 3 presents the desired theoretical properties, the weaknesses of the present prototype, the new criteria and their evaluation scales. The conclusion and future perspectives are discussed in Chapter 4.

This work was conducted at DREV in conjunction with Laval University between the months of june 1995 and april 1996 under Work Unit 3aa12: Commander's COA Advisor for Canadian airspace Violation (Ref. 2).

# 2.0 COMMANDER'S EXPERT SYSTEM ADVISOR (CESA)

The Commander's Expert System Advisor (CESA) is an advisor tool designed to assist the AOC (Air Operations Center, formerly FGOC) staff in prioritizing courses of action (COA) developed in response to an event. This decision aid tool can take a list of COAs, evaluate them with respect to certain factors and subfactors, and using priorities given by the Commander, obtain a ranking of these COAs and make suggestions to the Commander.

The main elements of CESA are events, courses of action (COA), options, factors and subfactors, and prioritization weights. The advisor tool uses these elements in order to evaluate and rank different COAs based on the factors and subfactors. We present below a description of CESA's elements as well as a summary of its current evaluation process.

## 2.1 Events

An event is defined as any situation to which the AOC staff must respond. It is characterized by a set of event conditions parameters. These parameters and their possible values are presented in Appendix A (Table I).

## 2.2 Courses of Action

A course of action (COA) is defined by a set of action items which describe the actions that a type of resource will perform as follows:

- What action should the resource perform at the destination?
- What equipment should be used?
- How much of each type of equipment is required?

- Where does it come from?
- Where is it going to?
- When should it depart from its present location?
- When should it arrive at its desired location?

A detailed description of the possible values of each action item are presented in Appendix B (Table II).

The COA features describe different facets of the COA. These are presented in Appendix C (Tables III and IV). They, along with the event condition parameters, are used in order to evaluate the COA with respect to the factors and subfactors.

### 2.3 Options

An option is any proposed COA which could constitute a response to an event. An option is characterized by a set of descriptive parameters which correspond to the values of the action items parameters.

### 2.4 Factors and Subfactors

A COA is evaluated with respect to factors and subfactors. The five factors are (Fig. 1):

- Flexibility: This factor is concerned with the ability to adapt to various possible changes that may occur in implementing a COA.

- Complexity: This factor is concerned with the implementation difficulty of a COA.

- Sustainability: This factor is the ability to continue (stay in) the operation.

- Optimum Use of Resources: This factor is concerned with the cost effectiveness of the resources being used.

- Risk: This factor is concerned with the possibility of mission failure and loss of equipment.

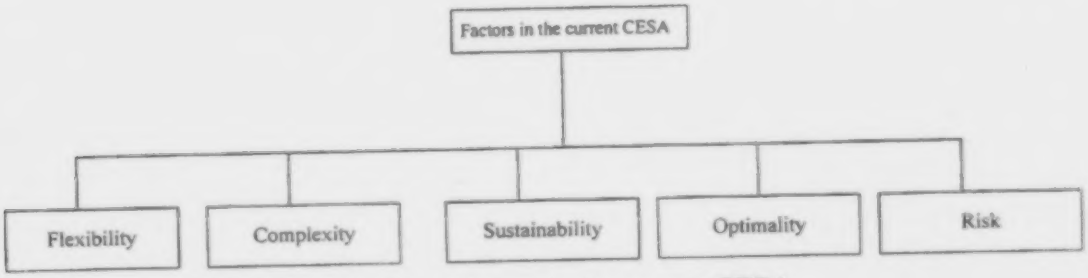


FIGURE 1 - Factors in the current CESA

The flexibility, complexity and risk factors are composed of subfactors as presented in Fig. 2. In total, there are five factors and 19 subfactors. A detailed description of the subfactors is provided in Appendix D. The subfactors Operations Complexity, Logistics Complexity, Command and Control Complexity, Area Of Operations (AOO) Complexity, Sensor Coverage and Equipment Failure (shaded in gray on Fig. 2) are further composed of subcomponents which we call indicators. These indicators correspond to COA features as described in Appendix C (Tables III and IV).

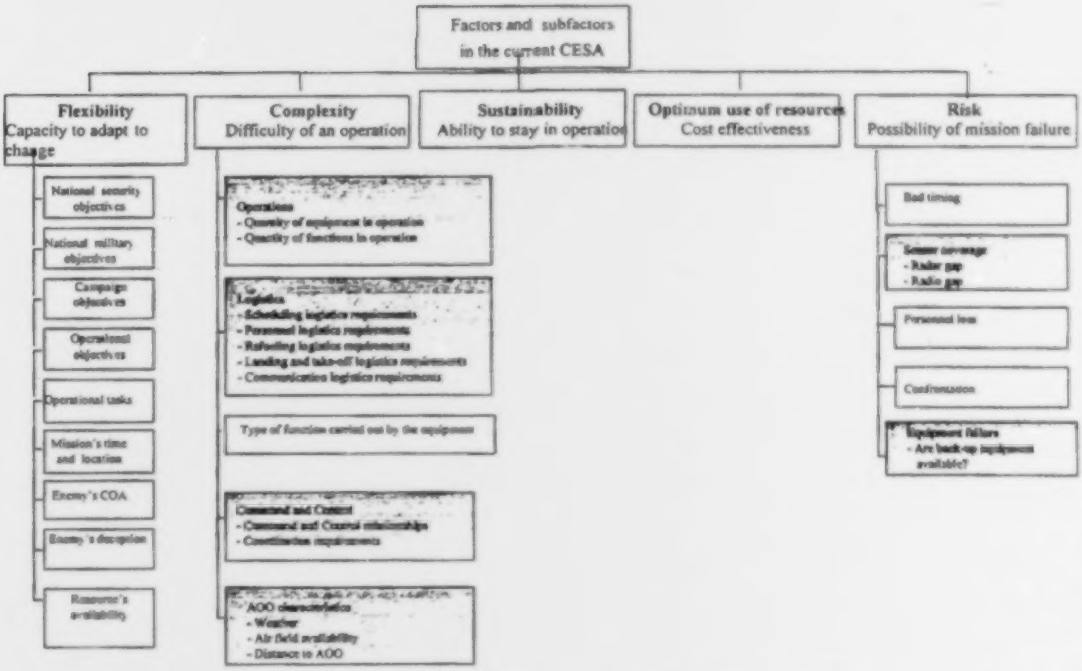


FIGURE 2 - Factors and subfactors in the current CESA

## 2.5 Prioritization Weights

The prioritization weights are a set of inputs which capture the Commander's priority given to each factor. The value which these weights can take are presented in Appendix E for each factor (Table V).

## 2.6 Evaluation of a COA

The evaluation of a COA with regard to the subfactors and the ranking process is summarized as follows:

- Describe an event by its event conditions parameters.

- Describe the different COAs by their action items and COA features.

- Obtain a final evaluation score for each COA by evaluating it with respect to the factors and subfactors, using the prioritization weights.

- Rank the COAs based on their final evaluation scores.

- Prioritize the COAs based on their ranking.

### 2.6.1 Final Evaluation Score

The final evaluation score of a COA option is obtained from a summation of its weighted scores on the five evaluation factors:

- The flexibility evaluation score of a COA option obtained from a normalized summation of its weighted scores on its nine subfactors.

- The complexity evaluation score of a COA option obtained from a normalized summation of its weighted scores on the four subfactors.

- The sustainability evaluation score.

- The optimality evaluation score.

- The risk evaluation score obtained from a normalized summations of the weighted scores on its six subfactors.

The procedures followed in order to obtain these evaluations are presented in Appendix F.

## 3.0 RESULTS OF THE CRITERIA REFORMULATION

### 3.1 Desirable Theoretical Properties

The family of criteria used in a multicriteria decision context must have certain theoretical properties in order to ensure a robust decision process. This family must be (Ref. 3):

- Readable: The number of criteria used must be relatively low.

- Operational: The family of criteria must be accepted by the stakeholders and the decision makers.

- Coherent: The coherence property implies that the criteria used are:

    - Exhaustive: The set of criteria used is exhaustive in the sense that the addition of a new criterion would not affect the result of the decision process when comparing two options.

    - Non-redundant: The criteria used must contribute to discriminate between different actions. Eliminating a criterion should have an impact on the result of the decision process and should render the criteria family non-exhaustive.

    - Cohesive: There must be consistency between the global and the local preference levels. For example, consider two options $a$ and $b$ which are

> indifferent on a global level. Suppose that $a'$ and $b'$ are 2 options obtained by degrading $a$ with respect to a criterion i and improving $b$ with respect to another criterion j. Then in a global sense, $b'$ must dominate $a'$.

Furthermore, it is preferable but not absolutely necessary that the criteria used be independent.

The factors and subfactors as defined in the current CESA do not meet the requirements of a coherent family of criteria as shown in Section 3.2.

### 3.2 Weaknesses of the Present Formulation in CESA

The scheme using the weighted average for evaluating the COAs with regard to the different factors (Appendix F) suggests that some implicit hypotheses have been made. These are the following:

- Independence: It is assumed that the sub-factors and factors are independent. This is not always the case in the present CESA formulation ( the same indicators are used to measure two different subfactors).

- Same importance: It is assumed that the indicators which measure a subfactor have equal importance in contributing to the evaluation. This is highly unlikely in practice.

- Non-conflicting: It is assumed that the indicators used in measuring a subfactor are non conflicting. This is not always the case in the present CESA formulation.

- Same scale: It is assumed that all factors can be measured on the same scale, which is a not always a realistic assumption.

Furthermore, the analysis of the set of factors and subfactors revealed that some subfactors were redundant, and that they were compensatory in the sense that a good performance on a criterion can counterbalance a bad performance on another criterion. This property is not always acceptable, in the case of comparing the loss of a life for example, with the cost of a mission.

In order to deal with this situation, the factors and subfactors of the current CESA were reformulated into a family of 14 criteria. The term dimension is used as a parallel to factor, and the term criterion refers to subfactor. The results are presented in Section 3.3.

### 3.3 The Reformulated Family of Criteria: Results

The reformulated family of criteria for the counterdrug scenario in a peace time normal context is composed of five dimensions (Flexibility, Complexity, Sustainability, Cost of Resources, Risk) which are divided into 14 criteria (Fig. 3).

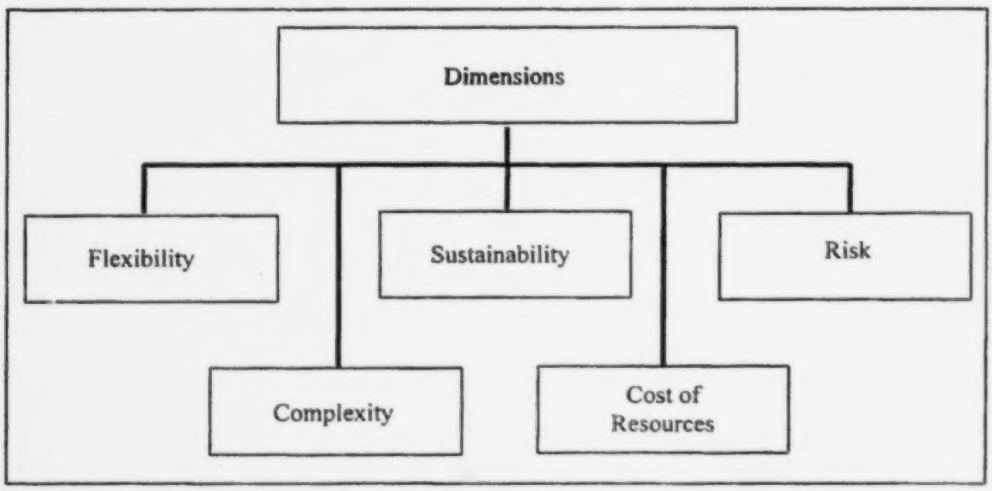


FIGURE 3 - Dimensions considered for the construction of the criteria

### 3.3.1 The Flexibility Dimension

The flexibility dimension is concerned with the ability to adapt to various possible changes that may occur while implementing a COA. This dimension is divided into three criteria as presented on Fig. 4: Covering Operational Tasks, Covering Mission's Possible Locations, and Covering Enemy's COA.

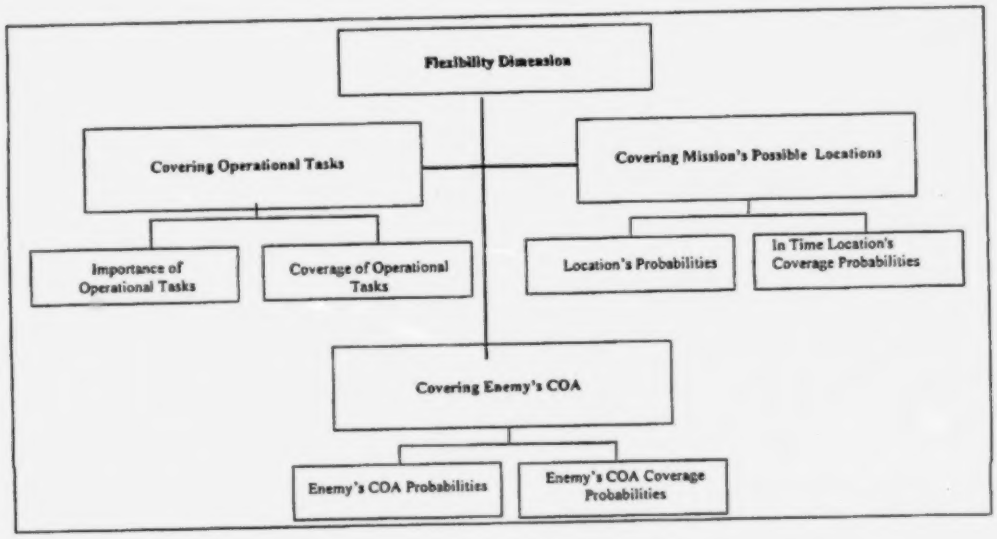


FIGURE 4 - Decomposition of the flexibility dimension

#### 3.3.1.1 Criterion 1: Covering Operational Tasks

This criterion is concerned with the ability of COA i ($COA_i$) to adapt to possible changes in operational task j ($OT_j$), which may occur during its implementation. This criterion is to be maximized.

The evaluation of $COA_i$ with respect to $C_1$ is given by $e_{i1} \in [0,1]$ as follows:

$$e_{i1} = \sum_{j=1}^{T_1} \pi_{OT_j} \cdot x_{ij} \qquad (1)$$

$$x_{ij} = \begin{cases} 1 & \text{if } COA_i \text{ covers } OT_j \\ \text{between} & 0 \text{ and } 1 \text{ if the task is partially covered} \\ 0 & \text{Otherwise} \end{cases}$$

$$\sum_{j=1}^{T_1} \pi_{OT_j} = 1$$

where $\pi_{OT_j}$ is the weight which reflects the relative importance of $OT_j$, $T_1$ is the total number of operational tasks identified by the staff, and $x_{ij}$ expresses the degree to which $COA_i$ covers the $OT_j$ with respect to criterion $C_1$. $OT_j$ can take one of 44 values such as: Monitor transport routes/ Coordinate with civilian and military units for joint operations/ Participate in detection, tracking and interdiction of narcotics transport/ Intercept communications, etc.

#### 3.3.1.2 Criterion 2: Covering Mission's Possible Locations

This criterion is concerned with the ability of a COA to adapt to possible changes in the predicted mission's locations which may occur during the implementation of a COA. This criterion is to be maximized.

Considering the weather conditions, the distance to AOO and AOO characteristics, the operator assesses the conditional probability $p_{time_{ij}}$ that $COA_i$ covers in time (no partial covering) the mission's location, given that it is $ML_j$ with probability $p_{ML_j}$, j=1,2,…,$T_2$. $T_2$ is the total number of mission's locations identified by the staff. A mission's possible location is specified by the coordinates of one of 521 sites which correspond to sites having landing and take-off facilities.

The evaluation of $COA_i$ with respect to $C_2$ is given by $e_{i2} \in [0,1]$ in the following manner:

$$e_{i2} = \sum_{j=1}^{T_2} p_{ML_j} \cdot p_{time_{ij}} \qquad (2)$$

#### 3.3.1.3 Criterion 3: Covering Enemy's COA

This criterion is concerned with the ability of a COA to adapt in time to possible changes in the enemy's COA that may occur during the implementation. This criterion is to be maximized.

The operator assesses the conditional probability $p_{cover_{ij}}$ that $COA_i$ covers in time the enemy's course of action given that the enemy executes $ECOA_j$ with probability $p_{ECOA_j}$, j=1,2,...,$T_3$. $T_3$ is the total number of possible enemy's courses of action. $ECOA_j$ can take one of the following values: Land and deployment/ air to land drop/ air to sea drop/ decoy/ testing run/deception. In the case of a deception, the value may then be one of: fake drop, several airplanes in sequence/ changing in heading/ changing destination/ circling/ under utilizing aircraft capabilities/ mimic commercial airliner/ formation and split.

The evaluation of $COA_i$ with respect to $C_3$ is given by $e_{i3} \in [0,1]$:

$$e_{i3} = \sum_{j=1}^{T_3} p_{ECOA_j} \cdot p_{cover_{ij}} \tag{3}$$

### 3.3.2 Complexity Dimension

This dimension is concerned with the implementation complexity of a COA. It is divided into three criteria: Operation Complexity, Logistic Complexity, and Command and Control Complexity (Fig. 5).

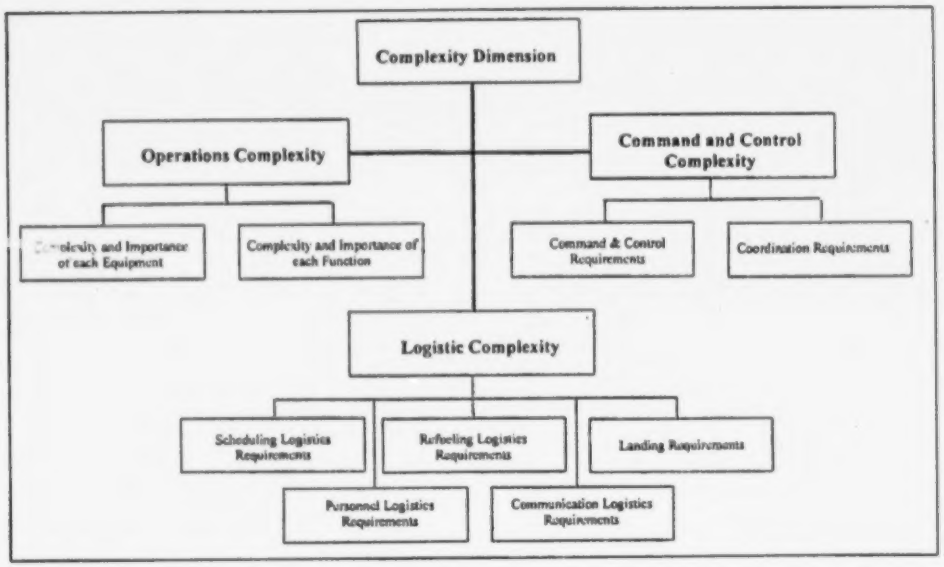


FIGURE 5 - The complexity dimension

### 3.3.2.1 Criterion 4: Operations Complexity

This criterion is concerned with the COA implementation difficulties caused by its operational requirements. This criterion is to be minimized.

For each equipment j in operation to execute $COA_i$ ($Equipment_{ij}$), and for each function to be performed by it, ($Function_{ijk_j}$), the operator assesses the complexity ($Comp_{ijk_j}$) of $Function_{ijk_j}$ on a (High, Medium, Low) scale by taking into account the AOO characteristics where $j=1,...,T_{i4}$, and $k_j=1,...,T_{i4j}$. $T_{i4}$ is the total number of equipments and $T_{i4j}$ is the total number of functions associated with equipment j of $COA_i$. The equipments may take one of the following values: Sensor/ Switch/ Comm-equipment/ Radar/ Channel/ Equipment (sensor)/ Site/ Search/ Select Id Feature/ Radar/ Common Digitize/ or 1 of 9 types of airplanes. The functions correspond to 13 possible actions which are: move/ request/ standby/ refuel/ communication/ monitor/ visual

identification/ transit/ force land/ shoot down/ direct out of space/ mark/ continue monitoring.

The evaluation of $COA_i$ with respect to $C_4$ is obtained by redefining a global ordinal scale with five levels using the number of High, Medium and Low evaluations obtained by the equipment. We aggregate the evaluations within each COA by defining $V_H$, $V_M$, $V_L$, as follows:

$$V_H = \sum_{j=1}^{T_{i4}} \sum_{k_j=1}^{T_{i4j}} \pi_{equip_{ij}} \cdot X_{ijk_j} \text{ with } X_{ijk_j} = \begin{cases} 1 & \text{if } Comp_{ijk_j} = \text{High} \\ 0 & \text{otherwise} \end{cases}$$

$$V_M = \sum_{j=1}^{T_{i4}} \sum_{k_j=1}^{T_{i4j}} \pi_{equip_{ij}} \cdot X_{ijk_j} \text{ with } X_{ijk_j} = \begin{cases} 1 & \text{if } Comp_{ijk_j} = \text{Medium} \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$V_L = \sum_{j=1}^{T_{i4}} \sum_{k_j=1}^{T_{i4j}} \pi_{equip_{ij}} \cdot X_{ijk_j} \text{ with } X_{ijk_j} = \begin{cases} 1 & \text{if } Comp_{ijk_j} = \text{Low} \\ 0 & \text{otherwise} \end{cases}$$

where $\pi_{equip_{ij}}$ is the relative importance of each $Equipment_{ij}$ to execute $COA_i$. We assume that the functions have equal importance. Now, using the evaluation vector ($V_L$, $V_M$, $V_H$), we build an ordinal scale of five levels for $e_{i4}$ according to the following rules:

$$\begin{cases} \text{if } V_H > V_L \text{ and} \begin{cases} \text{if } V_H > V_M \Rightarrow e_{i4} = 5 \\ \text{if } V_H \leq V_M \Rightarrow e_{i4} = 4 \end{cases} \\ \text{if } V_H < V_L \text{ and} \begin{cases} \text{if } V_M > V_L \Rightarrow e_{i4} = 2 \\ \text{if } V_M \leq V_L \Rightarrow e_{i4} = 1 \end{cases} \\ \text{if } V_H = V_L \Rightarrow e_{i4} = 3 \end{cases} \quad (5)$$

#### 3.3.2.2 Criterion 5: Logistics Complexity

This criterion is concerned with the COA implementation difficulties caused by its logistics requirements. This criterion is to be minimized.

For $COA_i$, the operator assesses its Scheduling Logistics Requirements $LR_{i1}$, Refueling Logistics Requirements $LR_{i2}$, Landing and Take-Off Logistics Requirements $LR_{i3}$, Communication Logistics Requirements $LR_{i4}$, Personnel Logistics Requirements $LR_{i5}$ and Resupply Requirements $LR_{i6}$ on a (High, Medium, Low) scale.

The evaluation of $COA_i$ with respect to $C_5$ given by $e_{i5}$ is obtained by rules similar to those of $e_{i4}$:

$$V_H = \sum_{j=1}^{6} \pi_{LR_{ij}} \cdot X_{ij} \quad \text{with} \quad X_{ij} = \begin{cases} 1 & \text{if } LR_{ij} = \text{High} \\ 0 & \text{otherwise} \end{cases}$$

$$V_M = \sum_{j=1}^{6} \pi_{LR_{ij}} \cdot X_{ij} \quad \text{with} \quad X_{ij} = \begin{cases} 1 & \text{if } LR_{ij} = \text{Medium} \\ 0 & \text{otherwise} \end{cases} \qquad (6)$$

$$V_L = \sum_{j=1}^{6} \pi_{LR_{ij}} \cdot X_{ij} \quad \text{with} \quad X_{ij} = \begin{cases} 1 & \text{if } LR_{ij} = \text{Low} \\ 0 & \text{otherwise} \end{cases}$$

Now, using the evaluation vector ($V_L$, $V_M$, $V_H$), we build a new ordinal scale at five levels for $e_{i5}$ according to the same rules as $e_{i4}$ (Equation 5).

#### 3.3.2.3 Criterion 6: Command and Control Complexity

This criterion is concerned with the COA implementation difficulties caused by Command and Control relationships and Coordination requirements in operation. This criterion is to be minimized.

For $COA_i$, the operator assesses the Command and Control relationships complexity $C_{ccr_i}$ and the coordination requirements complexity $C_{cr_i}$ on an ordinal scale of (Very High, High, Medium, Low, Very Low).

The evaluation of $COA_i$ with respect to $C_6$ is a vector (distributional) evaluation obtained by:

$$e_{i6}=(V1_{i6}, V2_{i6}, V3_{i6}, V4_{i6}, V5_{i6}) \quad (7)$$

where $C_{ccr_i}$ *and* $C_{cr_i}$ are combined by using $\pi_{ccr_i}$ and $\pi_{cr_i}$, the weights which reflect the importance of the corresponding complexities, as follows:

$$Vj_{i6}= \pi_{ccr_i} x_{ccr_{ij}} + \pi_{cr_i} x_{cr_{ij}}, \text{ j=1,...,5, and} \quad (8)$$

$x_{ccr_{i1}}$ =1 if $C_{ccr_i}$ = Very High, 0 otherwise

$x_{ccr_{i2}}$ =1 if $C_{ccr_i}$ = High, 0 otherwise

$x_{ccr_{i3}}$ =1 if $C_{ccr_i}$ = Medium, 0 otherwise

$x_{ccr_{i4}}$ =1 if $C_{ccr_i}$ = Low, 0 otherwise

$x_{ccr_{i5}}$ =1 if $C_{ccr_i}$ = Very Low, 0 otherwise

$x_{cr_{ij}}$ is defined in a similar fashion using the evaluation along $C_{cr_i}$.

### 3.3.3 Sustainability Dimension

This dimension is concerned with the ability to continue (stay in) the operation. It is represented by only on criterion : Sustainability (Fig. 6).

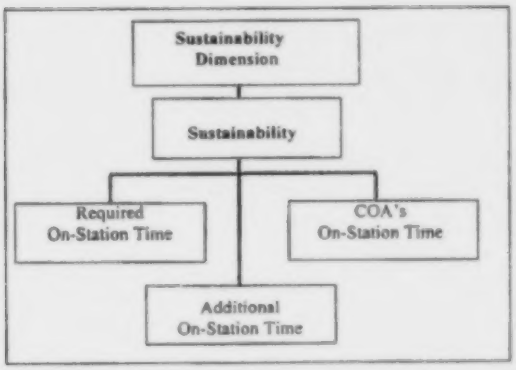


FIGURE 6 - Sustainability Dimension

#### 3.3.3.1 Criterion 7: Sustainability

This criterion is concerned with the ability to continue (stay in) the operation as a function of the on-station time associated with the COA. The higher the available on-station time, the higher the sustainability measure. This criterion is to be maximized.

The evaluation of $COA_i$ with respect to $C_7$ is given by $e_{i7} \geq 0$ and obtained as follows:

$$e_{i7} = \frac{T_{on-station_i} - T_{required}}{T_{required} + T_{additional}} \text{ if } T_{required} \leq T_{on-station_i}$$
$$0 \text{ Otherwise} \qquad (9)$$

where the values for required on-station time ($T_{required}$), and additional on-station time ($T_{additional}$) depend on the event, whereas $T_{on-station_i}$ is the available on-station time for $COA_i$.

### 3.3.4 Cost of Resources Dimension

This dimension is concerned with the cost of the resources being used. It is represented by only one criterion: Cost of Resources.

#### 3.3.4.1 Criterion 8: Cost of Resources

This criterion is concerned with the cost of the resources being used. This criterion is to be minimized.

The evaluation of $COA_i$ according to the $C_8$ is $e_{i8}$ where $Cost_{ij}$ is the variable cost, in dollars, associated with the use of the equipment j; $T_{i4}$ is the total number of equipments used in $COA_i$. It is given by:

$$e_{i8} = \sum_{j=1}^{T_{i4}} Cost_{ij} \tag{10}$$

### 3.3.5 Risk Dimension

This dimension represents the risks of mission failure as well as the risks associated with the mission. This dimension is developed into six criteria: Impact of the Sensors Coverage Gap, Military Personnel Loss, Collateral Damage, Confrontation Risk, COA Equipment Reliability, and COA Personnel Effectiveness (Fig. 7).

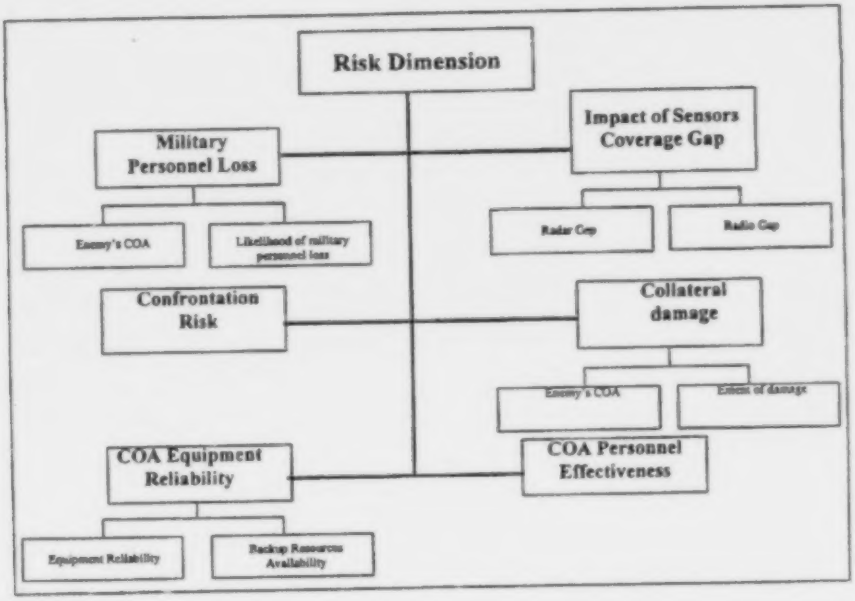


FIGURE 7 - Risk Dimension

#### 3.3.5.1 Criterion 9: Impact of the Sensors Coverage Gap

This criterion is concerned with the possibility of mission failure caused by the existence of radar and/or radio gaps. This criterion is to be minimized.

For $COA_i$, the operator assesses the risk of mission failure due to a radar gap ($gap_{radar_i}$), and/or a radio gap ($gap_{radio_i}$) on a (High, Medium, Low) scale. These evaluations are combined using the weights $\pi gap_{radar_i}$ and $\pi gap_{radio_i}$. These weights represent the importance of the impact of the associated gap. The evaluation of $COA_i$ with respect to $C_9$ given by $e_{i9}$ is a vector (distributional) evaluation obtained in a similar fashion to $C_6$ by the following aggregation:

$$e_{i9}=(V1_{i9}, V2_{i9}, V3_{i9}) \tag{11}$$

$$Vj_{i9}=\pi gap_{radio_i}\ xrad_j+\pi gap_{radar_i}\ xradr_j\ , j=1,...,3, \text{ and} \tag{12}$$

$xradr_1$ =1 if $gap_{radar_i}$ = High, 0 otherwise

$xradr_2$ =1 if $gap_{radar_i}$ = Medium, 0 otherwise

$xradr_3$ =1 if $gap_{radar_i}$ = Low, 0 otherwise

$xrad_j$ is defined in a similar fashion using the evaluation of $gap_{radio_i}$.

#### 3.3.5.2 Criterion 10: Military Personnel Loss

This criterion is concerned with the likelihood of military personnel loss during the mission. This criterion is to be minimized.

The operator assesses for $COA_i$ the likelihood of military personnel loss ($L_{MPL_{ij}}$) on an ordinal scale (Highly Likely, Very Likely, Likely, Unlikely, Highly Unlikely) given that the enemy executes $ECOA_j$ with probability ($p_{ECOA_j}$), j=1,2,…,$T_3$.

The evaluation of $L_{MPL_{ij}}$ is conditional to $ECOA_j$. These evaluations are aggregated by defining the following:

$$V_z = \sum_{j=1}^{T_j} p_{ECOA_j} \cdot x_{zij} \text{ , z=a,...,e} \tag{13}$$

where:

$$x_{aij} = 1 \text{ if } L_{MPL_{ij}} = \text{Highly Unlikely, 0 otherwise} \tag{14}$$

$x_{bij}$ =1 if $L_{MPL_{ij}}$ = Unlikely, 0 otherwise

$x_{cij}$ =1 if $L_{MPL_{ij}}$ = Likely, 0 otherwise

$x_{dij}$ =1 if $L_{MPL_{ij}}$ = Very Likely, 0 otherwise

$x_{eij}$ =1 if $L_{MPL_{ij}}$ = Highly Likely, 0 otherwise

Then, an ordinal scale for $e_{i10}$ with seven echelons is obtained as follows:

$$if\left[(V_a > V_e)\&(V_b > V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 1 \\ if(V_b = V_c) \Rightarrow e_{i10} = 2 \\ if(V_b < V_c) \Rightarrow e_{i10} = 3 \end{cases} \tag{15}$$

$$if\left[(V_a > V_e)\&(V_b = V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 2 \\ if(V_b = V_c) \Rightarrow e_{i10} = 3 \\ if(V_b < V_c) \Rightarrow e_{i10} = 4 \end{cases}$$

$$if\left[(V_a > V_e)\&(V_b < V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 3 \\ if(V_b = V_c) \Rightarrow e_{i10} = 4 \\ if(V_b < V_c) \Rightarrow e_{i10} = 5 \end{cases}$$

$$if\left[(V_a = V_e)\&(V_b > V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 2 \\ if(V_b = V_c) \Rightarrow e_{i10} = 3 \\ if(V_b < V_c) \Rightarrow e_{i10} = 4 \end{cases}$$

$$if\left[(V_a = V_e)\&(V_b = V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 3 \\ if(V_b = V_c) \Rightarrow e_{i10} = 4 \\ if(V_b < V_c) \Rightarrow e_{i10} = 5 \end{cases}$$

$$if\left[(V_a = V_e)\&(V_b < V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 4 \\ if(V_b = V_c) \Rightarrow e_{i10} = 5 \\ if(V_b < V_c) \Rightarrow e_{i10} = 6 \end{cases}$$

$$if\left[(V_a < V_e)\&(V_b > V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 3 \\ if(V_b = V_c) \Rightarrow e_{i10} = 4 \\ if(V_b < V_c) \Rightarrow e_{i10} = 5 \end{cases}$$

$$if\left[(V_a < V_e)\&(V_b = V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 4 \\ if(V_b = V_c) \Rightarrow e_{i10} = 5 \\ if(V_b < V_c) \Rightarrow e_{i10} = 6 \end{cases}$$

$$if\left[(V_a < V_e)\&(V_b < V_d)\right]\& \begin{cases} if(V_b > V_c) \Rightarrow e_{i10} = 5 \\ if(V_b = V_c) \Rightarrow e_{i10} = 6 \\ if(V_b < V_c) \Rightarrow e_{i10} = 7 \end{cases}$$

#### 3.3.5.3 Criterion 11: Collateral Damage

This criterion is concerned with the possibility of collateral damage (anything but the target) during the mission. This criterion is to be minimized.

For $COA_i$, the operator determines the extent of the expected collateral damage ($damage_{ij}$) given that the enemy executes $ECOA_j$ with probability ( $p_{ECOA_j}$ ), j=1,2,…,$T_3$. The evaluation of $damage_{ij}$ on a (Very High, High, Medium, Low, None) scale is conditional to $ECOA_j$. The evaluation of $e_{i11}$ on an ordinal scale of seven echelons is obtained by rules similar to $e_{i10}$ (Equation 15).

#### 3.3.5.4 Criterion 12: Confrontation Risk

This criterion is concerned with the possibility of mission failure due to confrontation. It is to be minimized.

For $COA_i$, the operator assesses the likelihood of confrontation ($Cr_{ij}$) given that the enemy executes $ECOA_j$ with probability ($p_{ECOA_j}$), j=1,2,...,$T_3$. This evaluation of $Cr_{ij}$ on an ordinal scale (Very Likely, Likely, Unlikely) is conditional to $ECOA_j$. The evaluation of $e_{i12}$ on an ordinal scale of five echelons is obtained by the same rules as $e_{i4}$ and $e_{i5}$.

#### 3.3.5.5 Criterion 13: COA Equipment Reliability

This criterion is concerned with the equipment reliability and the robustness of the COA. This is a cardinal evaluation which is computed automatically from the hazard rate $\lambda_j$ which is the inverse of Mean Times Between Failures of equipment j, j=1,...,$T_{i4}$. This criterion is to be maximized.

The evaluation $e_{i13}$ corresponding to the probability of no failure between the time 0 and t, is obtained automatically by taking into account the $COA_i$ equipment configuration, whether parallel, series or standby, and the hazard rate $\lambda_j$ (Ref. 4).

$$e_{i13}(t) = 1 - \prod_{j=1}^{T_{i4}} \left(1 - exp^{-\lambda_j t}\right) \text{ Parallel configuration} \tag{16}$$

$$e_{i13}(t) = \left(\prod_{j=1}^{T_{i4}} exp^{-\lambda_j t}\right) \text{ Series configuration}$$

### 3.3.5.6 Criterion 14: COA Personnel Effectiveness

This criterion is concerned with the effectiveness of the personnel which may be jeopardized by fatigue, stress, etc. at any moment during the mission. This criterion is to maximized.

For $COA_l$, and taking into account the complexity of the COA, the operator assesses the effectiveness of the personnel on a (Very Highly Effective, Very Effective, Effective, Lowly Effective, Very Lowly Effective) scale. This evaluation corresponds to $e_{l14}$ and is modeled as a fuzzy number (Ref. 5).

Figure 9 summarizes the different criteria presented. The first column identifies the criterion, the second identifies whether the criterion should be maximized or minimized, the third column identifies the type of individual scales used for the global evaluation of the COA with regard to the criterion. This evaluation can be deterministic or a probability value; it can be crisp (given by a single number) or distributional (given by a vector evaluation or a by a fuzzy number); it can also be continuous or discrete (an integer value).

| Criterion | Optimization | Scale characteristics |
|---|---|---|
| Covering Operational Tasks, $C_1$ | Maximize | Cardinal on [0,1], crisp |
| Covering Mission's locations, $C_2$ | Maximize | Cardinal on [0,1, crisp |
| Covering Enemy's COA, $C_3$ | Maximize | Cardinal on [0,1], crisp |
| Operations Complexity, $C_4$ | Minimize | Ordinal, 5 echelons, crisp |
| Logistics Complexity, $C_5$ | Minimize | Ordinal, 5 echelons, crisp |
| C+C Complexity, $C_6$ | Minimize | A discrete distribution on Ordinal, 5 echelons, crisp |
| Sustainability, $C_7$ | Maximize | Cardinal, $\mathbf{R}^+$, crisp |
| Cost of Resources, $C_8$ | Minimize | Cardinal, $\mathbf{R}^+$, crisp |
| Impact of Sensors Coverage Gap, $C_9$ | Minimize | A discrete distribution on Ordinal, 3 echelons, crisp |
| Military personnel loss, $C_{10}$ | Minimize | Ordinal, 7 echelons, crisp |
| Collateral damage, $C_{11}$ | Minimize | Ordinal, 7 echelons, crisp |
| Confrontation risk, $C_{12}$ | Minimize | Ordinal, 5 echelons, crisp |
| Equipment reliability, $C_{13}$ | Maximize | Cardinal on [0,1], crisp |
| Personnel effectiveness, $C_{14}$ | Maximize | Ordinal, 5 echelons, fuzzy |

FIGURE 8: A summary of the 14 criteria

## 4.0 CONCLUSIONS

In order to assist the Air Commander in his activity of ensuring the sovereignty of Canada, DREV has been working on developing an advisor tool for the evaluation, ranking, and selection of courses of action (COA). A first prototype called CESA (Commander's Expert System Advisor) was developed and demonstrated.

This memorandum presents the current state of CESA and the results of a research project aiming at improving the theoretical basis of this decision aid tool. This is done by reformulating the set of factors and subfactors as a family of 14 criteria, and by redefining their evaluation scales. This was done in order to ensure that the family of criteria possess the necessary theoretical properties, which increases the robustness of the decisions based on CESA. The scenario used is counterdrug operations in a peace time normal context.

The next step is to validate this new family of criteria and their evaluation scales to ensure that they represent well the scheme of thought of the decision maker (Commander) and that they form a coherent criteria family. This will be conducted as part of a current project following interviews with Air Command staff.

## 5.0 REFERENCES

1. CES, "Application Software Development/Software Maintenance Documentation", DO-35a, DND ATBMS-CESA, DND Contract #W8477-3-TJ02/01-SV, 27 mai 1997.

2. Martel, J. M., "Analyse des critères à utiliser dans un processus d'évaluation des suites d'actions envisageables", Contrat DND #W7701-6-1580, mars 1997.

3. Roy, B., "Méthodologie multicritère d'aide à la décision", Économica, Paris, 1985.

4. Kaufmann, A., "Modèles mathématiques pour l'étude de la fiabilité des systèmes", Masson, Paris, 1975.

5. Munda, G., "Multicriteria Evaluation in a Fuzzy Environment", Springer-Verlag, New York, 1995.

## APPENDIX A
## Event Condition Parameters

This appendix presents the event condition parameters which are variables describing an event. These parameters are:

a. Strategic Goals. Strategic achievements expected by higher headquarters.

b. Mission:
   1. Mission Statement: What the assigned forces will do, where they will operate, when the operations will commence, and why.
   2. Assigned Tasks: Tasks assigned by higher headquarters.
   3. Implied Tasks: Non-assigned tasks that must be carried out to prepare for and conduct assigned tasks.
   4. Constraints: The actions that must be done.
   5. Restraints: What must not be done.

c. Assumption:
   1. Current Situation: The supposition of the current course of events.
   2. Future Situation: The supposition of the future course of events.

d. Objectives:

   1. Objectives and Phases: How the operations run.
   2. End-State Definition: End-State of operations required by the Commander.
   3. Influence Factors: Factors that are likely to influence the mission.

   4. Success Criteria: The Commander's criteria of mission success.

e. Forces Assigned: Forces assigned by the Commander on the basis that they are available, and by capability grouping.

f. Considerations:
   1. Strategic Considerations: Strategic factors that must be considered in determining a course of action.

2. Political Considerations: Political factors that must be considered in determining a course of action.
3. Economic Considerations: Economical factors that must be considered in determining a course of action.
4. Centre of Gravity: Enemy's and own centre of gravity.
5. Main Effort: Main activities in the operations.
6. C&C Arrangements: Command and Control arrangements.
7. Theatre Boundaries: The boundaries of the operation theatre.
8. Administration Considerations: Administration factors that must be considered in determining a course of action.
9. Key Dates: Key dates in the operations.

g. Regulations: Applicable OPLANs/OPORDs and other regulations.

h. Environment:
1. Geography: Geographical characteristics of the operation area that must be considered.
2. Weather: Weather characteristics of the operation area and during the operation period that must be considered.
3. Social Characteristics: Social characteristics of the operation area that must be considered, such as culture, religion, etc.
4. Production Facilities: Industrial production facilities in the operation area.
5. Transportation Facilities: Transportation facilities in the operation area.
6. Energy Resource Facilities: Power plants and other energy resources in the operation area.
7. Communication Facilities: Communication systems in the operation area.

i. Enemy Forces:
1. Aircraft and Weapons: Enemy's aircraft and weapon resources.
2. Personnel and Skills: Enemy's personnel resources, their training and their technical readiness.
3. Intelligence Capabilities: Enemy's intelligence facilities and capabilities.
4. Planning Capabilities: Enemy's planning facilities and capabilities.

5. Supply Capabilities: Enemy's supply facilities and capabilities.
6. Maintenance Capabilities: Enemy's maintenance facilities and capabilities.
7. Communication Capabilities: Enemy's communication facilities and capabilities.
8. Reinforcement Capabilities: Enemy's reinforcement facilities and capabilities.
9. C&C Capabilities: Enemy's command and control facilities and capabilities.

j. Enemy Intention:
1. Course of Action: Possible course of action of an enemy.
2. Alternatives: Possible alternative courses of action of an enemy.
3. Deception: Possible deception.

k. Own Forces:
1. Aircrafts and Weapons: Own aircraft and weapon resources.
2. Personnel and Skills: Own personnel resources, their training and their technical readiness.
3. Intelligence Capabilities: Own intelligence facilities and capabilities.
4. Planning Capabilities: Own planning facilities and capabilities.
5. Supply Capabilities: Own supply facilities and capabilities.
6. Maintenance Capabilities: Own maintenance facilities and capabilities.
7. Communication Capabilities: Own communication facilities and capabilities.
8. Reinforcement Capabilities: Own reinforcement facilities and capabilities.
9. C&C Capabilities: Own command and control facilities and capabilities.

The possible values that event condition parameters can take are presented in the following table:

TABLE I

Event condition parameters

| Parameter | Value |
|---|---|
| National Security Objectives: | See Table IV for detailed listing |
| National Military Objectives: | See Table IV for detailed listing |
| Theatre/Campaign Objectives: | See Table IV for detailed listing |
| Operational Objectives: | See Table IV for detailed listing |
| Operational Tasks: | See Table IV for detailed listing |
| Mission Location and Time: Where the mission is expected to be conducted. | Manokotak / Abrek Bay-Naval / Sault Ste Marie / Halifax / Pelly Bay / Namao / Comox / Trenton / Vancouver-Intl / Winnipeg Intl / Abbotsford / North Bay / Charlottetown / Churchill / Elmendorf / Bagotville / Cold Lake / Gander / Yellowknife / Greenwood / Coastal Area / Rankin / EPAT A |
| Enemy Course of Action: | land and deployment / air to land drop / air to sea drop / decoy / testing run |
| Enemy Deception: | fake drop / several airplanes in sequence / changing heading / changing destination / circling / under utilizing aircraft capabilities / mimic commercial airliner / formation and split |
| Weather Conditions in AOO: AOO is Area of Operations | green / yellow / red |
| Air Field Availability in AOO: | green / yellow / red |
| Required On-Station Time: The duration of that a readiness stance is to be maintained at the on station location. | numerical value expressed in minutes |
| Possible Additional Required On-Station Time: The duration of that a on station readiness stance might have to be maintained beyond the expected duration. | numerical value expressed in minutes |
| Mission-Mission Statement (What): | unknown / preplanned |
| Mission-Mission Statement (Where): | over land / over sea |

| | |
|---|---|
| Mission-Mission Statement (When): | as soon as possible / await further notice / as directed |
| Mission-Mission Statement (Why): | Undefined |
| Mission-Implied Tasks: | do not be detected / co-ordinate with external agencies |
| Mission-Assigned Tasks: | gather G2 on their detection capabilities / test for any new weapons postures |
| Mission-Constraints: | must use all equipment types / must involve US / duration must be less than 20 hours / duration must be greater than 20 hours |
| Mission-Restraints: | must not use Auroras / must not inform local municipal police unit |
| Assumptions-Current Situation-Mission Type: | counter-drug type 1 / counter-drug type 2 / counter-drug type 3 / allow multiple missions occurring concurrently |
| Assumptions-Current Situation-Mission: | mission 1 / mission 2 / mission 3 |
| Assumptions-Future-Situation-Mission Type: | shadow/monitor / forced landing / CAP / hijack / terrorist / air defence / air intercept |
| Assumptions-Future Situation-Mission: | mission 1 / mission 2 / mission 3 |
| Objectives-Objectives and Phases: | Peace Time Normal |
| Objectives-Influence Factors: | Peace Time Normal |
| Objectives-Success Criteria: | Peace Time Normal |
| Objectives: | obtain shipment / positive ID of unknown / exercise co-ordinate with other agencies / obtain drug runner plane / obtain drug runners / mark drug spot / continue monitoring |
| Forces Assigned: Friendly forces. | CF18 / Aurora / KC135 / 707 / EWACS (E3) / TS70-mobile-radar / Hercules / T133 / Foreign Resources (DEA) / Ships / CF144 |
| Considerations-Political Considerations: | Peace Time Normal |
| Considerations-Economic Considerations: | cannot allocate more than 20 hours per plane |
| Considerations-Centre of Gravity: | North Bay / Wings / Columbia / landing fields / Deployed Sites |
| Considerations-Primary Effort: | Peace Time Normal |
| Considerations-C&C Arrangements: | Peace Time Normal |
| Considerations-Theatre Boundaries: | North / South / Canada / Atlantic Canada |
| Considerations-Admin. Considerations: | Peace Time Normal |
| Considerations-Key Dates: | must be ended by Tuesday / Must start by Monday |
| Environment-Geography Condition: | City / Mountains / Water |
| Environment-Weather: | green / yellow / red |

| | |
|---|---|
| Environment-Social Characteristics: | pilots might not speak English / might be part of fanatic religious group |
| Environment-Production Facilities: | Peace Time Normal |
| Environment-Transportation Facilities: | Peace Time Normal |
| Environment-Energy Resource Facilities: | Peace Time Normal |
| Environment-Communications Facilities: | Peace Time Normal |
| Enemy Forces-Aircraft and Weapon: | Military Aircraft / Beechcraft 200 (Sierra) / Beechcraft 36 (Bonanza) / Cessna 172 (Skyhawk) / Cessna 180,185 (Skywagon) / Cessna 182 (Skylane) / Cessna 206 (Stationair 6) / Cessna 210 (Centurion) / Cessna 208 (Caravan) / Piper PA-28,32 (Cherokee) / Piper PA-46 (Malibu) / Beechcraft B58 (Baron) / Beechcraft B80 (Queen Air) / Beechcraft B90,100 (King Air) / Beechcraft B200 (Super King Air) / Cessna 303 (Crusader) / Cessna 310 / Cessna 337 / Cessna 401,402,414 (Businessliner) / Cessna 441 (Conquest) / Piper PA-23 (Aztec) / Piper PA-34 (Seneca III) / Piper PA-30 (Twin Commanche) / Piper PA-31P (Navajo) / Piper PA-31-350 (Navajo Chieftain) / Piper PA-42 (Cheyenne III) / Rockwell Aerocommander 680 / Cessna Citation II Model 550 / Dassault Falcon 10 / Gates Learjet 25 / Gates Learjet 35,36 / Gulfstream III / Lockheed Jetstar II / Rockwell Sabreliner / De Havilland DHC-6 (Twin Otter) / Douglas DC-3 (Dakota) / Douglas DC-6 / Convair CV-580 / Antanov-32 (Cline) / Antanov 72,74 (Coaler) |
| Enemy Forces-Personnel and Skills: | good / poor / over reactive |
| Enemy Forces-Intelligence Capabilities: | Peace Time Normal |
| Enemy Forces-Planning Capabilities: | Peace Time Normal |
| Enemy Forces-Supply Capabilities: | Peace Time Normal |
| Enemy Forces-Maintenance Capabilities: | Peace Time Normal |
| Enemy Forces-Communications Capabilities: | Radar Warning Receivers / Cellular Phones / Radio / Morse Code Units |
| Enemy Forces-Reinforcement Capabilities: | Peace Time Normal |
| Enemy Forces-C&C Capabilities: | Peace Time Normal |
| Enemy Intention-Course of Action: | land and deployment / air to land drop / air to sea drop / decoy / testing run |

| | |
|---|---|
| Enemy Intention-Alternatives: | land and deployment / air to land drop / air to sea drop / decoy / testing run |
| Enemy Intention-Deception: | fake drop / several airplanes in sequence / change heading / changing destination / circling / under utilizing aircraft capabilities / formation and split |
| Enemy Intention-Earliest Time of Arrival: | Undefined |
| Own Forces-Aircraft and Weapon: | Peace Time Normal |
| Own Forces-Personnel and Skills: | Peace Time Normal |
| Own Forces-Intelligence Capabilities: | probability of faulty G2 is <50% / probability of faulty G2 is >50% |
| Own Forces-Planning Capabilities: | Peace Time Normal |
| Own Forces-Supply Capabilities: | Peace Time Normal |
| Own Forces-Maintenance Capabilities: | Peace Time Normal |
| Own Forces-Communications Capabilities: | Peace Time Normal |
| Own Forces-Reinforcement Capabilities: | Peace Time Normal |
| Own Forces-C&C Capabilities: | Peace Time Normal |

## APPENDIX B

### Action Item Parameters

This appendix presents the action item parameters which describe the action that a resource will perform (Table II).

TABLE II

Action item parameters

| Parameter | Value |
|---|---|
| Action: What is the function that the resource is to perform, more than one function is possible. | move/request/standby/refuel/communication/ monitor/visual-identification/transit/force land /shoot down/direct out of space/mark/continue monitoring |
| Equipment: What resource is to be used. | CF18 / Aurora / KC135 / 707 / EWACS (E3) / TS70-mobile-radar / Hercules / T133 / Foreign Resources (DEA) / Ships / CF144 |
| Quantity: How many of this type of resources for this action are to be used. | Numerical value |
| From: Where should the aforementioned resource come from. | Manokotak / Abrek Bay Naval / Sault Ste Marie / Halifax / Pelly Bay / Namao / Comox / Trenton / Vancouver-Intl / Winnipeg-Intl / Abbotsford / North Bay / Charlottetown / Churchill / Elmendorf / Bagotville / Cold Lake / Gander / Yellowknife / Greenword / Coastal Area / Rankin / EPAT A |
| To: Where should the resource go to. | Manokotak / Abrek Bay Naval / Sault Ste Marie / Halifax / Pelly Bay / Namao / Comox / Trenton / Vancouver-Intl / Winnipeg-Intl / Abbotsford / North Bay / Charlottetown / Churchill / Elmendorf / Bagotville / Cold Lake / Gander / Yellowknife / Greenword / Coastal Area / Rankin / EPAT A |
| Start: What is the start time for this action. | Numerical value |
| Finish: What is the finish time for this action. | Numerical value |

| | |
|---|---|
| Are Back up Resources Available (ARA): Are backup resources of the type mentioned or a suitable alternate available. This is used to indicate the ability to replace aircraft which fail to take off. For example, prior to the take off of the assigned aircraft are there backups should the assigned aircraft fail to take off. | yes / maybe / no |
| AIT: Will the resource arrive on station in time to perform its assigned action. | yes / maybe / no |
| Remarks: | |

## APPENDIX C

## COA Features

This appendix presents the COA features which describe a COA (Table III) and the values which the national objectives can take (Table IV).

TABLE III

COA features

| Parameter | Value |
|---|---|
| National Security Objectives Coverage: | See Table IV for detailed listing |
| National Military Objectives Coverage: | See Table IV for detailed listing |
| Theatre/Campaign Objectives Coverage: | See Table IV for detailed listing |
| Operational Objectives Coverage: | See Table IV for detailed listing |
| Operational Tasks Coverage: | See Table IV for detailed listing |
| Enemy COA Coverage: Which possible enemy COAs can be covered with the proposed COA. | land and deployment / air to land drop / air to sea drop / decoy / testing run |
| Enemy Deception Coverage: Which possible enemy deceptions can be covered with the proposed COA. | fake drop / several airplanes in sequence / changing heading / changing destination / circling / under utilizing aircraft capabilities / mimic commercial airliner / formation and split |
| Quantity of Equipment in Operations: How many pieces of equipment will be airborne in the AOO. | low / medium / high |
| Quantity of Functions in Operations: What is the expected number of functions or duties the each resources is expected to carry out. For example radio and radar is two functions. | low / medium / high |
| Type of Function Difficulty: Is the type of function or task that the pilots are being asked to perform difficult, e.g. an air-to-air intercept is perhaps easier than a ground strike. | low / medium / high |
| Scheduling Logistics Requirements: Overall is scheduling a problem. | low / medium / high |

| | |
|---|---|
| Personnel Logistics Requirements: Will availability or crews or rotation of personnel be a problem. | low / medium / high |
| Refueling Logistics Requirements: Is refueling readily available or will complex procedures be required. | low / medium / high |
| Landing and Take-off Logistics Requirements: Will repeated landings and takeoffs be required. | low / medium / high |
| Communication Logistics Requirements: Will communications be a problem. | low / medium / high |
| Command and Control Relationships: Will command and control be divided. | Single / Pair or Shared / Multiple |
| Coordination Requirements: Will our group have to co-ordinate with other groups. | none / with other military forces / with police / with other government agencies / combination |
| Distance to AOO: Will traveling to the Area of Operations require refueling. | no refueling requirement / one leg / two legs / multiple legs |
| On-Station Time: What is the duration of on station time possible with the proposed COA. | numerical value expressed in minutes. |
| Use of Surplus Resources in Addition to SOP Allocation: Does the COA have more resources than indicated as the acceptable minimum according to standard operating procedures. | no / yes |
| Radar Gap: Will there be a radar gap. | none / small / medium / large / very large |
| Radio Gap: Will there be a radio gap. | none / small / medium / large / very large |
| Personnel Safety: | very safe / maybe / unsafe |
| Drug Smuggler Weapon Capability: | none / gun / missile |
| Inverse of accident Rate (# of hours per 1 accident): On average what is the number of hours between accidents. For example, if 5 accidents occur every 100,000 hours or 5/10000 then 1 accident is expected every 20,000 hours. | numerical value expressed in hours. |

Table IV gives the complete list of possible objective values starting at the National Military Objective. These are values that some of the COA features and the event condition parameters can take. In order to make the chart more readable the first two columns do not repeat the objective name in the following entries. For example, the name of the Theatre/Campaign Objective ("Deter aggression") in row No. 1 is not

repeated in row No. 2 although it is still "Deter Aggression". When the objective changes the new name is shown.

## TABLE IV

Possible values of national objectives

| No. | National Military Objective | Theatre/ Campaign Objectives | Operational Objectives | Operational Tasks |
|---|---|---|---|---|
| 1 | Conduct military operations for the defence of Canada, North America, NATO - Europe allies, and victims of aggression elsewhere / | Deter aggression / | Gather timely and accurate intelligence / | Monitor orders of battle and movements |
| 2 | | | Gather timely and accurate intelligence / | Provide indicators and early warning of attack |
| 3 | | | Gather timely and accurate intelligence / | Prepare and update target lists |
| 4 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Detect\|assess threatening changes in adversary forces' disposition |
| 5 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Provide warning of military activities of interest |

| | | | | |
|---|---|---|---|---|
| 6 | | | Provide timely threat warning and attack assessment of ballistic or cruise missile attack / | Provide TW\|AA of missile attack in order to disperse forces for survival |
| 8 | | | Provide timely threat warning and attack assessment of ballistic or cruise missile attack / | Provide TW\|AA of missile attack to promote survival of national and military leadership |
| 9 | | | Maintain access to and control of space assets / | Provide interference-resistant, survivable satellites and associated systems |
| 10 | | | Maintain access to and control of space assets / | Coordinate shared use of assets |
| 11 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications between deployed forces and national C2 |
| 12 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications with coalition\|alliance C2 structure\|units |
| 13 | | | Provide C4 support to friendly operations / | Coordinate joint\|combined operations |
| 14 | | | Provide C4 support to friendly operations / | Maintain survivable command facilities |
| 15 | | | Provide C4 support to friendly operations / | Maintain high-capacity, jam-resistant communication networks with all echelons |

| | | | | |
|---|---|---|---|---|
| 16 | | | Deter attacks within theatre by weapons of mass destruction / | Maintain survivable command facilities |
| 17 | | | Deter attacks within theatre by weapons of mass destruction / | Maintain high-capacity,jam-resistant communication networks with all echelons |
| 18 | | | Provide for operations security / | Establish perimeter security for bases\|facilities |
| 19 | | | Provide for operations security / | Maintain physical security of pers and equipment enroute and during operations |
| 20 | | | Provide assistance to host nation's military services / | Provide training for allied forces |
| 21 | | | Provide assistance to host nation's military services / | Provide logistics support |
| 22 | | | Provide assistance to host nation's military services / | Provide common equipment to enhance interoperability |
| 23 | | | Maintain credible deployment capability / | Exercise periodically within theatre |
| 24 | | | Maintain credible deployment capability / | Identify training, equipment and infrastructure shortages\|deficiencies |
| 25 | | | Prepare for adequate mobility of combat power / | Maintain capability to move pers\|reinforcements, equipment and supplies within theatre |

| | | | | |
|---|---|---|---|---|
| 26 | | | Prepare for adequate mobility of combat power / | Maintain capability to move pers\|reinforcements, equipment and supplies into theatre |
| 27 | | | Prepare for adequate mobility of combat power / | Maintain capability to coordinate effective joint and combined airlift\|sealift operations |
| 28 | | | Prepare for adequate mobility of combat power / | Maintain capability to airdrop personnel and supplies in remote areas |
| 29 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Coordinate actions to correct deficiencies |
| 30 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Establish liaison with domestic and foreign industry\|contracted providers |
| 31 | | | Prepare to operate in NBC and Electronic Warfare environments / | Identify training, equipment and infrastructure shortages\|deficiencies |
| 32 | | | Prepare to operate in NBC and Electronic Warfare environments / | Conduct NBC and EW training |
| 33 | | | Provide for area defence of Lines of Communication / | Conduct joint and combined surveillance\| reconnaissance |

| | | | | |
|---|---|---|---|---|
| 34 | | | Provide for area defence of Lines of Communication / | Conduct joint and combined aerospace control operations |
| 35 | | | Provide for area defence of Lines of Communication / | Conduct joint and combined maritime control operations |
| 36 | | | Provide for area defence of Lines of Communication / | Conduct joint and combined exercises |
| 37 | | | Provide for area defence of Lines of Communication / | Provide\|Maintain surveillance systems |
| 38 | | | Provide operations, logistics, admininstrative, training support / | Provide ATC\|Mel support |
| 39 | | | Provide operations, logistics, administrative, training support / | Provide joint and combined EW training support |
| 40 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 41 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 42 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 43 | | Conduct combat operations / | Gather timely and accurate intelligence / | Monitor orders of battle and movements |
| 44 | | | Gather timely and accurate intelligence / | Provide indicators and early warning of attack |

| | | | | |
|---|---|---|---|---|
| 45 | | | Gather timely and accurate intelligence / | Prepare and update target lists |
| 46 | | | Gather timely and accurate intelligence / | Maintain environmental and mapping data on potential operating areas |
| 47 | | | Gather timely and accurate intelligence / | Locate and track selected relocatable\|mobile targets |
| 48 | | | Gather timely and accurate intelligence / | Assess attack damage |
| 49 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Detect\|assess threatening changes in adversary forces' disposition |
| 50 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Provide warning of military activities of interest |
| 51 | | | Provide timely threat warning and attack assessment of ballistic or cruise missile attack / | Provide TW\|AA of missile attack in order to disperse forces for survival |
| 52 | | | Provide timely threat warning and attack assessment of ballistic or cruise missile attack / | Provide TW\|AA of missile attack to promote survival of national and military leadership |

| | | | | |
|---|---|---|---|---|
| 53 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications between deployed forces and national C2 |
| 54 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications with coalition\|alliance C2 structure\|units |
| 55 | | | Provide C4 support to friendly operations / | Coordinate joint\|combined operations |
| 56 | | | Provide C4 support to friendly operations / | Maintain survivable command facilities |
| 57 | | | Provide C4 support to friendly operations / | Maintain high-capacity, jam-resistant communication networks with all echelons |
| 58 | | | Provide C4 support to friendly operations / | Provide forward air control |
| 59 | | | Provide adequate mobility of combat power / | Move pers\|reinforcements, equipment and supplies within theatre |
| 60 | | | Provide adequate mobility of combat power / | Move pers\|reinforcements, equipment and supplies into theatre |
| 61 | | | Provide adequate mobility of combat power / | Airdrop personnel, equipment and supplies in remote areas |

| | | | | |
|---|---|---|---|---|
| 62 | | | Provide adequate mobility of combat power / | Coordinate effective joint and combined airlift\|sealift operations |
| 63 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Coordinate actions to correct shortages\| deficiencies |
| 64 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Maintain support system with domestic and foreign industry\|contracted providers |
| 65 | | | Provide air refueling support for theatre forces / | Refuel aircraft in transit to theatre |
| 66 | | | Provide air refueling support for theatre forces / | Refuel aircraft involved in operations |
| 67 | | | Provide air refueling support for theatre forces / | Coordinate joint and combined air refueling |
| 68 | | | Provide replenishment at sea for theatre forces / | Refuel ships |
| 69 | | | Provide replenishment at sea for theatre forces / | Resupply ships |
| 70 | | | Enact measures to enhance survivability / | Inhibit damage through hardening, redundancy, dispersal, camouflage, concealment, deception |

| | | | | |
|---|---|---|---|---|
| 71 | | | Rapidly restore facilities\|units after attack / | Provide rapid damage assessment |
| 72 | | | Rapidly restore facilities\|units after attack / | Provide rapid repair\|reconstruction capability |
| 73 | | | Suppress\|destroy weapons of mass destruction and their production\|storage facilities / | Destroy factories\|weapon storage sites\|launch facilities |
| 74 | | | Suppress\|destroy weapons of mass destruction and their production\|storage facilities / | Deny access to key sites and materiel |
| 75 | | | Defeat adversary air attack / | Detect, intercept and destroy aircraft in flight |
| 76 | | | Defeat adversary air attack / | Damage\|destroy aircraft at their airfields |
| 77 | | | Defeat adversary air attack / | Disrupt\|damage\|destroy C4 assets and facilities |
| 78 | | | Defeat adversary air attack / | Disrupt\|damage\|destroy aviation support assets and facilities |
| 79 | | | Suppress generation of adversary aircraft sorties / | Damage\|destroy airfield runways and taxiways |
| 80 | | | Suppress generation of adversary aircraft sorties / | Damage\|destroy aircraft in operation and sheltered |
| 81 | | | Suppress generation of adversary aircraft sorties / | Damage\|destroy airfield support facilities |

| | | | | |
|---|---|---|---|---|
| 82 | | | Degrade\|destroy effectiveness of adversary air defences / | Suppress\|damage\|destroy adversary early warning radars |
| 83 | | | Degrade\|destroy effectiveness of adversary air defences / | Supperss\|damage\|destroy adversary mobile or fixed SAMs and AAA |
| 84 | | | Degrade\|destroy effectiveness of adversary air defences / | Supperss\|damage\|destroy adversary airborne or fixed C4 |
| 85 | | | Degrade\|destroy effectiveness of adversary air defences / | Provide self-protection for penetrating aircraft |
| 86 | | | Defeat adversary ballistic or cruise missile attacks / | Detect, intercept and destroy missiles in flight |
| 87 | | | Defeat adversary ballistic or cruise missile attacks / | Damage\|destroy missiles at their launch sites |
| 88 | | | Defeat adversary ballistic or cruise missile attacks / | Disrupt\|damage\|destroy C4 assets and facilities |
| 89 | | | Defeat adversary ballistic or cruise missile attacks / | Disrupt\|damage\|destroy support assets and facilities |
| 90 | | | Degrade\|destroy C4 and fixed high value targets / | Damage\|destroy command facilities |
| 91 | | | Degrade\|destroy C4 and fixed high value targets / | Disrupt adversary communications |
| 92 | | | Degrade\|destroy C4 and fixed high value targets / | Eliminate key commanders |

| | | | | |
|---|---|---|---|---|
| 93 | | | Degrade\|destroy C4 and fixed high value targets / | Disrupt\|damage\|destroy fixed SAM systems and EW/GCI sites |
| 94 | | | Degrade\|destroy C4 and fixed high value targets / | Damage\|destroy key facilities at airfields, garrisons, depots and other sites |
| 95 | | | Degrade\|destroy C4 and fixed high value targets / | Destroy\|sabotage adversary equipment |
| 96 | | | Disrupt\|damage\|destroy mobile targets / | Distrupt\|damage\|destroy armored units |
| 97 | | | Disrupt\|damage\|destroy mobile targets / | Distrupt\|damage\|destroy mechanized units |
| 98 | | | Disrupt\|damage\|destroy mobile targets / | Distrupt\|damage\|destroy TELs |
| 99 | | | Disrupt\|damage\|destroy mobile targets / | Distrupt\|damage\|destroy mobile SAM systems and EW/GCI sites |
| 100 | | | Destroy adversary forces in close proximity to friendly forces / | Disrupt\|destroy adversary forces by direct attack |
| 101 | | | Destroy adversary forces in close proximity to friendly forces / | Damage\|destroy armoured\| mechanized vehicles near FEBA |
| 102 | | | Destroy adversary forces in close proximity to friendly forces / | Disable\|destroy dismounted troops |

| | | | | |
|---|---|---|---|---|
| 103 | | | Destroy adversary forces in close proximity to friendly forces / | Suppress adversary helicopters operations from forward locations |
| 104 | | | Destroy adversary forces in close proximity to friendly forces / | Suppress\|destroy adversary artillery and multiple rocket launchers |
| 105 | | | Delay, disrupt or destroy forces moving to contact and combat support elements / | Disrupt adversary bases of operation by direct attack |
| 106 | | | Delay, disrupt or destroy forces moving to contact and combat support elements / | Disrupt\|damage\| destroy armor and other vehicles en marche, or in defensive positions |
| 107 | | | Disrupt\|destroy adversary LCOs and field logistics sites / | Disrupt\|damage\|dest roy field logistic sites, transportation nodes, and assembly areas |
| 108 | | | Disrupt\|destroy adversary LCOs and field logistics sites / | Disrupt\|deny\|destroy Lines of Communication |
| 109 | | | Defeat breakthrough assaults / | Disrupt\|destroy adversary forces by direct attack |
| 110 | | | Defeat breakthrough assaults / | Damage\|destroy armored vehicles near the FEBA |
| 111 | | | Defeat breakthrough assaults / | Disable\|destroy dismounted troops |
| 112 | | | Defeat breakthrough assaults / | Suppress adversary helicopters operations from forward locations |

| | | | | |
|---|---|---|---|---|
| 113 | | | Defeat breakthrough assaults / | Suppress\|destroy adversary artillery and multiple rocket launchers |
| 114 | | | Provide operations security for rear area and key facilities\|units / | Establish perimeter security for bases' facilities |
| 115 | | | Provide operations security for rear area and key facilities\|units / | Maintain physical security of pers and equipment enroute and during operations |
| 116 | | | Defend land, sea and air LOCs / | Conduct mine countermeasures |
| 117 | | | Defend land, sea and air LOCs / | Detect, intercept and destroy attacking forces |
| 118 | | | Disrupt\|destroy adversary naval surface forces / | Disable\|sink adversary combat and vessels by direct attack |
| 119 | | | Disrupt\|destroy adversary naval surface forces / | Mine ports, choke points and anchorages |
| 120 | | | Disrupt\|destroy adversary naval surface forces / | Disrupt or disable ship sensors |
| 121 | | | Disrupt\|destroy adversary naval subsurface forces / | Disable\|sink adversary combat and vessels by direct attack |
| 123 | | | Disrupt\|destroy adversary naval subsurface forces / | Mine ports, choke points and anchorages |
| 124 | | | Disrupt\|destroy adversary naval subsurface forces / | Disrupt or disable ship sensors |
| 125 | | | Disrupt\|destroy adversary naval port facilities / | Mine ports, choke points and anchorages |

| | | | | |
|---|---|---|---|---|
| 126 | | | Disrupt\|destroy adversary naval port facilities / | Damage\|destroy key facilities |
| 127 | | | Maintain operations of space assets / | Provide additional satellites |
| 128 | | | Maintain operations of space assets / | Reduce vulnerability to interference attempts |
| 129 | | | Maintain operations of space assets / | Maintain secure, robust ground interface |
| 130 | | | Rescue\|evacuate wounded personnel and noncombatants in distress / | Locate, prepare and secure landing zones and recovery bases |
| 131 | | | Rescue\|evacuate wounded personnel and noncombatants in distress / | Rescue personnel or land or at sea |
| 132 | | | Rescue\|evacuate wounded personnel and noncombatants in distress / | Retrieve\|disable\|destroy sensitive equipment |
| 133 | | | Rescue\|evacuate wounded personnel and noncombatants in distress / | Coordinate effective joint and combined evacuation operations |
| 134 | | | Rescue\|evacuate wounded personnel and noncombatants in distress / | Provide immediate medical attention |
| 135 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Assist in meeting legal and moral obligations to population |

| | | | | |
|---|---|---|---|---|
| 136 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Minimize civilian interference with military operations |
| 137 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Assist government in reestablishing services disrupted by military action |
| 138 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Promote peaceful behaviour and pro-Canadian behaviour among POWs |
| 139 | | | Reduce adversary leadership's will to wage war / | Damage\|destroy key political organizations and leadership cadres |
| 140 | | | Reduce adversary leadership's will to wage war / | Proliferate misinformation among the public at large |
| 141 | | | Reduce adversary leadership's will to wage war / | Disseminate misinformation and propaganda among adversary troops |
| 142 | | | Reduce adversary's public and military support for their leadership and war effort / | Sabotage selected sites associated with economic infrastructure |
| 143 | | | Reduce adversary's public and military support for their leadership and war effort / | Proliferate misinformation among the public at large |
| 144 | | | Reduce adversary's public and military support for their leadership and war effort / | Disseminate misinformation and propaganda among adversary troops |

| | | | | |
|---|---|---|---|---|
| 145 | | | Reduce adversary's industrial capacity to support war effort / | Damage\|destroy military R and D facilities |
| 146 | | | Reduce adversary's industrial capacity to support war effort / | Damage\|destroy war supporting industries |
| 147 | | | Reduce adversary's industrial capacity to support war effort / | Damage\|destroy critical power generation facilities and other key economic infrastructures |
| 148 | | | Reduce adversary's industrial capacity to support war effort / | Damage\|destroy transportation facilities and networks |
| 149 | | | Provide operations, logistics, administrative, training support / | Provide ATC\|Met support |
| 150 | | | Provide operations, logistics, administrative, training support / | Provide joint and combine EW training support |
| 151 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 152 | | | Provide operations, logistics, administrative, training support / | Provide pers and financial services |
| 153 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |

| | | | | |
|---|---|---|---|---|
| 154 | | Conduct post conflict operations / | Provide adequate mobility of combat power / | Redeploy pers\|reinforcements, equipment and supplies with theatre |
| 155 | | | Provide adequate mobility of combat power / | Coordinate effective joint and combined airlift\|sealift operations |
| 156 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Assist in meeting legal and moral obligations to population |
| 157 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Minimize civilian interference with military operations |
| 158 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Distribute food and water |
| 159 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Provide for temporary shelters |
| 160 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Assist government in reestablishing services disrupted by military action |
| 161 | | | Pacify\|provide humanitarian assistance to population and capture combatants / | Promote peaceful behaviour and pro-Canadian behaviour among POWs |
| 162 | | | Assist in establishing civil authority / | Provide support for enforcement of law and order |

| | | | | |
|---|---|---|---|---|
| 163 | | | Assist in rebuilding infrastructure / | Help restore basic services disrupted by conflict |
| 164 | | | Reduce antagonist's public\|military support for future hostilities / | Distribute information to the public at large |
| 165 | | | Reduce antagonist's public\|military support for future hostilities / | Disseminate misinformation and propaganda among adversary troops |
| 166 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 167 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 168 | | | Provide operations, logistics, administrative, training support / | Provide pers and financial services |
| 169 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 170 | Provide Support to Other Canadian Government Departments / | Provide Search and Rescue / | Conduct Search and Rescue operations / | Search for missing pers |
| 171 | | | Conduct Search and Rescue operations / | Rescue pers |
| 172 | | | Conduct Search and Rescue operations / | Conduct medical evacuation |
| 173 | | | Conduct Search and Rescue operations / | Provide immediate attention |

| | | | | |
|---|---|---|---|---|
| 174 | | | Provide operations, logistics, administrative, training support / | Operate RCCs |
| 175 | | | Provide operations, logistics, administrative, training support / | Coordinate satellite support |
| 176 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 177 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 178 | | | Provide operations, logistics, administrative, training support / | Provide pers and financial services |
| 179 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 180 | | Participate in disaster relief and humanitarian assistance / | Provide C4 support to friendly operations / | Establish\|maintain timely communications with civilian\|military C2 structure\|units |
| 181 | | | Provide C4 support to friendly operations / | Coordinate with civilian\|military units for joint operations |
| 182 | | | Provide for adequate mobility of support pers and materiel / | Move personnel , equipment and supplies within theatre |

| | | | | |
|---|---|---|---|---|
| 183 | | | Provide for adequate mobility of support pers and materiel / | Airdrop personnel and supplies in remote areas |
| 184 | | | Provide for adequate mobility of support pers and materiel / | Coordinate effective joint airlift\|sealift operations |
| 185 | | | Assist in rebuilding infrastructure / | Help restore basic services |
| 186 | | | Assist in rebuilding infrastructure / | Help restore public facilities and transport |
| 187 | | | Assist in rebuilding infrastructure / | Identify\|coordinate capabilities\|technologies to assist rebuilding |
| 188 | | | Provide humanitarian support / | Provide sanitation and disease control |
| 189 | | | Provide humanitarian support / | Distribute\|provide food, water, temporary shelter |
| 190 | | | Provide humanitarian support / | Provide medical, dental care |
| 191 | | | Provide humanitarian support / | Coordinate support services |
| 192 | | | Rescue\|evacuate civilian\|military pers in distress / | Locate and prepare landing zones and recovery bases |
| 193 | | | Rescue\|evacuate civilian\|military pers in distress / | Rescue personnel on land or at sea |
| 194 | | | Rescue\|evacuate civilian\|military pers in distress / | Coordinate effective evacuation operations |
| 195 | | | Rescue\|evacuate civilian\|military pers in distress / | Provide immediate medical attention |

| | | | | |
|---|---|---|---|---|
| 196 | | | Provide logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 197 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 198 | | | Provide logistics, administrative, training support / | Provide collective and individual training |
| 199 | | Provide Aid to the Civil Power / | Provide C4 support to friendly operations / | Establish\|maintain timely communications with civil\|military C2 structure\|units |
| 200 | | | Provide C4 support to friendly operations / | Coordinate with civil\|military units for joint operations |
| 201 | | | Assist in establishing civil authority / | Provide support for enforcement of law and order |
| 202 | | | Provide adequate mobility of combat power / | Move personnel reinforcements, equipment and supplies within theatre |
| 203 | | | Provide adequate mobility of combat power / | Coordinate effective joint airlift\|sealift operations |
| 204 | | | Provide logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |

| | | | | |
|---|---|---|---|---|
| 205 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 206 | | | Provide logistics, administrative, training support / | Provide effective and individual training |
| 207 | | Provide VIP transport / | Provide mobility support / | Move personnel, equipment and supplies |
| 208 | | | Provide operations, transport, logistics, administrative, training support / | Provide C4 support |
| 209 | | | Provide operations, transport, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 210 | | | Provide operations, transport, logistics, administrative, training support / | Provide personnel and financial services |
| 211 | | | Provide operations, transport, logistics, administrative, training support / | Provide collective and individual training |
| 212 | | Participate in counter-terrorism / | Gather timely and accurate intelligence / | Profile threat individuals and groups |
| 213 | | | Gather timely and accurate intelligence / | Intercept communications |
| 214 | | | Gather timely and accurate intelligence / | Coordinate with national\|international law enforcement\|military organizations |

| | | | | |
|---|---|---|---|---|
| 215 | | | Provide C4 support / | Establish\|maintain timely communications with civil\|military C4I structure\|units |
| 216 | | | Provide C4 support / | Coordinate with civilian\|military units for joint operations |
| 217 | | | Provide operations security / | Establish perimeter security for bases\|facilities |
| 218 | | | Provide operations security / | Maintain physical security of personnel and equipment enroute and during operations |
| 219 | | | Disrupt\|defeat terrorist attacks / | Defeat terrorists by direct attack |
| 220 | | | Disrupt\|defeat terrorist attacks / | Damage\|destroy means of transport\|support elements |
| 221 | | | Disrupt\|defeat terrorist attacks / | Disrupt terrorist C4I and training |
| 222 | | | Rescue\|evaluate civilian\|military personnel in distress / | Locate and prepare landing zones and recovery bases |
| 223 | | | Rescue\|evaluate civilian\|military personnel in distress / | Rescue personnel on land or at sea |
| 224 | | | Rescue\|evaluate civilian\|military personnel in distress / | Retrieve\|disable\|destroy sensitive equipment |

| | | | | |
|---|---|---|---|---|
| 225 | | | Rescue\|evaluate civilian\|military personnel in distress / | Coordinate effective evacuation operations |
| 226 | | | Rescue\|evaluate civilian\|military personnel in distress / | Provide immediate medical attention |
| 227 | | | Provide mobility support / | Move personnel\|reinforcements, equipment and supplies within theatre |
| 228 | | | Provide logistics, administrative, training support / | Provide engineering, maintenance, communications, supply support\|services |
| 229 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 230 | | | Provide logistics, administrative, training support / | Provide collective and individual training |
| 231 | | Participate in counter-narcotics / | Gather timely and accurate intelligence / | Profile threat individuals and groups |
| 232 | | | Gather timely and accurate intelligence / | Intercept communications |
| 233 | | | Gather timely and accurate intelligence / | Monitor transport routes |
| 234 | | | Gather timely and accurate intelligence / | Coordinate with national\| international law enforcement\| military organizations |

| | | | | |
|---|---|---|---|---|
| 235 | | | Provide C4 support / | Establish\|maintain C4 links with national\| international law enforcement\| military organizations |
| 236 | | | Provide C4 support / | Coordinate with civilian\|military units for joint operations |
| 237 | | | Disrupt narcotics operations / | Participate in detection, tracking and interdiction of narcotics transport |
| 238 | | | Provide operations security / | Establish perimeter security for bases\|facilities |
| 239 | | | Provide operations security / | Maintain physical security of personnel and equipment enroute and during operations |
| 240 | | | Provide logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 241 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 242 | | | Provide logistics, administrative, training support / | Provide collective and individual training |
| 243 | | Participate in National Identity Development / | Maintain positive image of DND/CF / | Conduct public displays and demonstrations |

| | | | | |
|---|---|---|---|---|
| 244 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 245 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 246 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 247 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 248 | | Participate in fisheries protection / | Gather timely and accurate intelligence / | Monitor areas and routes |
| 249 | | | Gather timely and accurate intelligence / | Coordinate with national\| international operations |
| 250 | | | Assist in enforcement of national\| international laws and agreements / | Participate in detection, tracking and interdiction of suspected violators |
| 251 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 252 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |

| | | | | |
|---|---|---|---|---|
| 253 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 254 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 255 | | Participate in environmental protection / | Gather timely and accurate intelligence / | Monitor areas and routes |
| 256 | | | Gather timely and accurate intelligence / | Coordinate with national\| international operations |
| 257 | | | Assist in enforcement of national\| international laws and agreements / | Participate in detection, tracking and interdiction of suspected violators |
| 258 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 259 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 260 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 261 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |

| | | | | |
|---|---|---|---|---|
| 262 | Provide Support to Canada-US bilateral arrangements and domestic contingencies / | Participate in research, development, and production / | Conduct research and development / | Provide research and development facilities |
| 263 | | | Conduct research and development / | Establish\|maintain contracts with industry\|academia |
| 264 | | | Conduct research and development / | Support relevant educational opportunities |
| 265 | | | Conduct research and development / | Share information |
| 266 | | | Support defence related production / | Maintain cooperative relationship with industry |
| 267 | | | Provide operations, logistics, administrative, training support / | Provide C4I support |
| 268 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 269 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 270 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 271 | | Participate in testing and evaluation / | Conduct test and evaluation / | Share use of test facilities |

| | | | | |
|---|---|---|---|---|
| 272 | | | Provide operations, logistics, administrative, training support / | Provide C4I support |
| 273 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 274 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 275 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 276 | | Participate in disaster relief and humanitarian assistance / | Provide C4 support to friendly operations / | Establish\|maintain timely communications with civilian\|military C2 structure\|units |
| 277 | | | Provide C4 support to friendly operations / | Coordinate with civilian\|military units for joint and combined operations |
| 278 | | | Provide for adequate mobility of support personnel and materiel / | Move personnel, equipment and supplies within theatre |
| 279 | | | Provide for adequate mobility of support personnel and materiel / | Airdrop personnel and supplies in remote areas |

| | | | | |
|---|---|---|---|---|
| 280 | | | Provide for adequate mobility of support personnel and materiel / | Coordinate effective joint and combined airlift\|sealift operations |
| 281 | | | Assist in rebuilding infrastructure / | Help restore basic services |
| 282 | | | Assist in rebuilding infrastructure / | Help restore public facilities and transport |
| 283 | | | Assist in rebuilding infrastructure / | Identify\|coordinate capabilities\|technologies to assist rebuilding |
| 284 | | | Provide humanitarian support / | Provide sanitation and disease control |
| 285 | | | Provide humanitarian support / | Distribute\|provide food, water and temporary shelter |
| 286 | | | Provide humanitarian support / | Provide medical, dental care |
| 287 | | | Provide humanitarian support / | Coordinate support services |
| 288 | | | Rescue\|evacuate personnel in distress / | Locate and prepare landing zones and recovery bases |
| 289 | | | Rescue\|evacuate personnel in distress / | Rescue personnel or land or at sea |
| 290 | | | Rescue\|evacuate personnel in distress / | Coordinate effective evacuation operations |
| 291 | | | Rescue\|evacuate personnel in distress / | Provide immediate medical attention |

| | | | | |
|---|---|---|---|---|
| 292 | | | *Provide logistics,* administrative, training support / | *Provide* engineering, maintenance, transport, communications, supply support\|services |
| 293 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 294 | | | Provide logistics, administrative, training support / | Provide collective and individual training |
| 295 | Participate in multi-lateral support operations (UN, NATO, other agreements) / | Participate in peacekeeping / | Gather and share timely and accurate intelligence / | Profile threat individuals and groups |
| 296 | | | Gather and share timely and accurate intelligence / | Intercept communications |
| 297 | | | Gather and share timely and accurate intelligence / | Monitor combats and movements |
| 298 | | | Gather and share timely and accurate intelligence / | Provide indicators and early warning of attack |
| 299 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Detect\|assess threatening changes in adversary forces' disposition |
| 300 | | | Provide decision makers with timely and accurate information on adversary disposition and intentions / | Provide warning of military activities of interest |

| | | | | |
|---|---|---|---|---|
| 301 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications with coalition\|alliance C2 structure\|units |
| 302 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications between deployed forces and national C2 |
| 303 | | | Provide C4 support to friendly operations / | Coordinate with coalition\|alliance forces for combined operations |
| 304 | | | Provide C4 support to friendly operations / | Maintain survivable command facilities |
| 305 | | | Provide C4 support to friendly operations / | Maintain high-capacity, jam-resistant communication networks with all echelons |
| 306 | | | Rescue\|evacuate wounded personnel and noncombatants / | Locate, prepare and secure landing zones and recovery bases |
| 307 | | | Rescue\|evacuate wounded personnel and noncombatants / | Rescue personnel or land or at sea |
| 308 | | | Rescue\|evacuate wounded personnel and noncombatants / | Retrieve\|disable\|destroy sensitive equipment |
| 309 | | | Rescue\|evacuate wounded personnel and noncombatants / | Conduct special operations |
| 310 | | | Rescue\|evacuate wounded personnel and noncombatants / | Coordinate effective evacuation operations |

| | | | | |
|---|---|---|---|---|
| 311 | | | Rescue\|evacuate wounded personnel and noncombatants / | Provide immediate medical attention |
| 312 | | | Provide for adequate mobility of personnel, materiel / | Move personnel, equipment and supplies in theatre |
| 313 | | | Provide for adequate mobility of personnel, materiel / | Provide transport for personnel, equipment and supplies in theatre |
| 314 | | | Provide for adequate mobility of personnel, materiel / | Airdrop personnel and supplies in remote areas |
| 315 | | | Provide for adequate mobility of personnel, materiel / | Coordinate effective joint and combined airlift\|sealift operations |
| 316 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Coordinate actions to correct shortages\| deficiencies |
| 317 | | | Provide adequate supplies of spares, POL, munitions and consumables to support prolonged combat operations / | Maintain support system with domestic, host national and international industry\|contract providers |
| 318 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Assist in meeting legal and moral obligations to indigenous population |

| | | | | |
|---|---|---|---|---|
| 319 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Distribute food and water |
| 320 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Provide for temporary shelters |
| 321 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Minimize civilian interference with military operations |
| 322 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Assist government in reestablishing services disrupted by military action |
| 323 | | | Pacify\|provide humanitarian assistance to population and capture combatants in liberated\|occupied areas / | Promote peaceful behaviour and pro-Canadian behaviour among POWs |
| 324 | | | Monitor and enforce compliance with international agreements and UN resolutions / | Enforce exclusion zones |

| | | | | |
|---|---|---|---|---|
| 325 | | | Monitor and enforce compliance with international agreements and UN resolutions / | Monitor Lines of Communication |
| 326 | | | Monitor and enforce compliance with international agreements and UN resolutions / | Participate in blockades and embargoes |
| 327 | | | Monitor and enforce compliance with international agreements and UN resolutions / | Participate in arms control measures |
| 328 | | | Provide assistance to allied nation's military / | Provide training for allied forces |
| 329 | | | Provide assistance to allied nation's military / | Provide logistics support |
| 330 | | | Provide assistance to allied nation's military / | Provide common equipment to enhance interoperability |
| 331 | | | Provide operations security / | Establish perimeter security for bases\|facilities |
| 332 | | | Provide operations security / | Maintain physical security of personnel enroute and during operations |
| 333 | | | Assist in establishing or maintaining civil authority / | Provide support for enforcement of law and order in the occupied territory |
| 334 | | | Reduce antagonists' public\|military support for hostilities / | Distribute information to the public at large |

| | | | | |
|---|---|---|---|---|
| 335 | | | Reduce antagonists' public\|military support for hostilities / | Disseminate misinformation on and propaganda among antagonists' troops |
| 336 | | | Assist in rebuilding infrastructure / | Help restore basic services disrupted by conflict |
| 337 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |
| 338 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 339 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 340 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 341 | | Participate in disaster and humanitarian assistance / | Provide C4 support to friendly operations / | Establish\|maintain timely communications with coalition\|alliance C2 structure\|units |
| 342 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications between deployed forces and national C2 |

| | | | | |
|---|---|---|---|---|
| 343 | | | Provide C4 support to friendly operations / | Coordinate with coalition\|alliance forces for combined operations |
| 344 | | | Provide C4 support to friendly operations / | Maintain survivable command facilities |
| 345 | | | Provide C4 support to friendly operations / | Maintain high-capacity, jam-resistant communication networks with all echelons |
| 346 | | | Provide for adequate mobility personnel, materiel / | Move personnel, equipment and supplies into theatre |
| 347 | | | Provide for adequate mobility personnel, materiel / | Provide transport for personnel, equipment and supplies in theatre |
| 348 | | | Provide for adequate mobility personnel, materiel / | Airdrop personnel and supplies into remote areas |
| 349 | | | Provide for adequate mobility personnel, materiel / | Coordinate effective joint and combined airlift\|sealift operations |
| 350 | | | Assist in rebuilding infrastructure / | Help restore basic services |
| 351 | | | Assist in rebuilding infrastructure / | Help restore public facilities and transport |
| 352 | | | Assist in rebuilding infrastructure / | Identify\|coordinate capabilities\|technologies to assist rebuilding |
| 353 | | | Rescue\|evacuate civilian\|military personnel in distress / | Locate, prepare and secure landing zones and recovery bases |

| | | | | |
|---|---|---|---|---|
| 354 | | | Rescue\|evacuate civilian\|military personnel in distress / | Rescue personnelonnel on land or at sea |
| 355 | | | Rescue\|evacuate civilian\|military personnel in distress / | Coordinate effective evacuation operations |
| 356 | | | Rescue\|evacuate civilian\|military personnel in distress / | Provide immediate medical attention |
| 357 | | | Assist in establishing civil authority / | Provide support for enforcement of law and order in the occupied territory |
| 358 | | | Provide humanitarian support / | Provide sanitation and disease control |
| 359 | | | Provide humanitarian support / | Distribute\|provide food, water, temporary shelter |
| 360 | | | Provide humanitarian support / | Provide medical, dental care |
| 361 | | | Provide humanitarian support / | Coordinate support services |
| 362 | | | Provide operations, logistics, administrative, training support / | Train indigenous personnel to provide basic and services |
| 363 | | | Provide operations, logistics, administrative, training support / | Provide C4 support |

| | | | | |
|---|---|---|---|---|
| 364 | | | Provide operations, logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 365 | | | Provide operations, logistics, administrative, training support / | Provide personnel and financial services |
| 366 | | | Provide operations, logistics, administrative, training support / | Provide collective and individual training |
| 367 | | Provide evacuation of Canadian citizens / | Rescue\|evacuate civilian\|military personnel in distress / | Locate, prepare and secure landing zones and recovery bases |
| 368 | | | Rescue\|evacuate civilian\|military personnel in distress / | Rescue personnel on land or at sea |
| 369 | | | Rescue\|evacuate civilian\|military personnel in distress / | Conduct special operations |
| 370 | | | Rescue\|evacuate civilian\|military personnel in distress / | Retrieve\|disable\| destroy sensitive equipment |
| 371 | | | Rescue\|evacuate civilian\|military personnel in distress / | Coordinate effective evacuation operations |
| 372 | | | Rescue\|evacuate civilian\|military personnel in distress / | Provide immediate medical attention |

| | | | | |
|---|---|---|---|---|
| 373 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications with coalition\|alliance C2 structure\|units |
| 374 | | | Provide C4 support to friendly operations / | Establish\|maintain timely communications between deployed forces and national C2 |
| 375 | | | Provide C4 support to friendly operations / | Coordinate with coalition\|alliance forces for joint and combined operations |
| 376 | | | Provide C4 support to friendly operations / | Maintain survivable command facilities |
| 377 | | | Provide C4 support to friendly operations / | Maintain high-capacity, jam-resistant communication networks with all echelons |
| 378 | | | Provide logistics, administrative, training support / | Provide engineering, maintenance, transport, communications, supply support\|services |
| 379 | | | Provide logistics, administrative, training support / | Provide personnel and financial services |
| 380 | | | Provide logistics, administrative, training support / | Provide collective and individual training |

## APPENDIX D

## FACTORS AND SUBFACTORS

This appendix describes the five factors and 19 subfactors used for evaluating COA's.

**Flexibility:** Flexibility is concerned with the ability to adapt to various possible changes that may occur in implementing a COA.

National Security Objectives Change Flexibility: The National Security Objectives Change Flexibility is concerned with the ability to adapt to possible changes in national security objectives that may occur in implementing a COA.

National Military Objectives Change Flexibility: The National Military Objectives Change Flexibility is concerned with the ability to adapt to possible changes in national military objectives that may occur in implementing a COA.

Campaign Objectives Change Flexibility: The Campaign Objectives Change Flexibility is concerned with the ability to adapt to possible changes in campaign objectives that may occur in implementing a COA.

Operational Objectives Change Flexibility: The Operational Objectives Change Flexibility is concerned with the ability to adapt to possible changes in operational objectives that may occur in implementing a COA.

Operational Tasks Change Flexibility: The Operational Tasks Change Flexibility is concerned with the ability to adapt to possible changes in operational tasks that may occur in implementing a COA.

Mission's Time and Location Change Flexibility: The Mission's Time and Location Change Flexibility is concerned with the ability to adapt to possible changes in mission's time and location that may occur in implementing a COA.

Enemy's Course of Action Change Flexibility: The Enemy's Course of Action Change Flexibility is concerned with the ability to adapt to possible changes in Enemy's Course of Action that may occur in implementing a COA.

Enemy's Deception Change Flexibility: The Enemy's Deception Change Flexibility is concerned with the ability to adapt to possible changes in Enemy's Deception that may occur in implementing a COA.

Resource Availability Change Flexibility: The Resource Availability Change Flexibility is concerned with the ability to adapt to possible changes in resource availability that may occur in implementing a COA.

**Complexity**: The complexity is concerned with how difficult the implementation of a COA would be.

Operations Complexity: The Operations Complexity is concerned with the COA implementation difficulties caused by COA operational requirements. This is made of of two components:

Quantity of Equipment in Operation: How many pieces of equipment will be airborne in the AOO.

Quantity of Function in Operations: What is the expected number of functions or duties each resource is expected to carry out. For example radio and radar are two functions.

Logistics Complexity: The Logistics Complexity is concerned with the COA implementation difficulties caused by COA logistics requirements. This is composed of the following components:

Scheduling Logistics Requirements: Is the overall scheduling a problem.
Personnel Logistics Requirements: Will availability of crews or rotation of personnel be a problem.
Refueling Logistics Requirements: Is refueling readily available or will complex procedures be required.
Landing and Take-off Logistics Requirements: Will repeated landings and takeoffs be required.
Communication Logistics Requirements: Will communications be a problem.

Type of Function Difficulty Complexity: This is the type of function of task that the pilots are being asked to perform difficult e.g. an air to air intercept is perhaps easier than a ground strike.

Command and Control Complexity: The Command and Control Complexity is concerned with the COA implementation difficulties caused by command and control relationships and coordination requirements in operations. This is made up of the following components:

Command and Control Relationships: Will command and control be divided.
Coordination Requirements: Will our group have to co-ordinate with other groups.

AOO Characteristics Complexity: The AOO Characteristics Complexity is concerned with the COA implementation difficulties caused by AOO characteristics. This is composed of the following components:

Weather: the weather in the AOO

Airfield Availability: the availability of an airfield in the AOO.

Distance to AOO: Will traveling to the Area of Operations require refueling.

**Sustainability**. The ability to continue (stay in) the operation.

**Optimum Use of Resources Evaluation.** The Optimum Use of Resources is concerned with the cost effectiveness of the resources being used.

**Risk**. The risk is concerned with the possibility of mission failure and loss of equipment. It should be noted that bad weather potentially impacts the following risks and should be considered when evaluating the following risks. In addition, while a confrontation could cause personnel loss, this could be due to other causes. Thus personnel loss and confrontation risk should be considered as separate items.

Bad Timing Risk: The Bad Timing Risk is concerned with the possibility of mission failure caused by some of the assigned resources that cannot be deployed to the area of operations to execute COA in time.

Sensor Coverage Gap Risk: The Sensor Coverage Gap Risk is concerned with the possibility of mission failure caused by the existence of uncovered sensor (radar and radio) gaps. This is comprised of the following components:

Radar Gap: Will there be a radar gap.
Radio Gap: Will there be a radio gap.

Personnel Loss Risk. The Personnel Loss Risk is concerned with the possibility of mission failure caused by the personnel safety problem.

Confrontation Risk: The Confrontation Risk is concerned with the possibility of mission failure and equipment loss caused by drug smuggler's weapon capability.

Equipment Failure Risk: The Equipment Failure Risk is concerned with the possibility of mission failure caused by mechanical failure of equipment. This is comprised of the following components:

Are backup Resources Available (ARA): Are backup resources of the type mentioned or a suitable alternate available. This is used to indicate the ability to replace aircraft which fail to take off. For example, prior to the take-off of the assigned aircraft are there backups should the assigned aircraft fail to take off.

The in-flight risk of failure: After-take off what is the risk of equipment failure.

## APPENDIX E

### Prioritization Weights

This appendix describes the prioritization weights that capture the Commander's priority given to each factor (Table V). Risk and Complexity are generally considered to be inversely related to the other three factors. A value of very important for Flexibility, Sustainability and Optimum Use of Resources means to maximize these factors. While a value of Very Important to Complexity and Risk means to minimize these factors.

TABLE V

Prioritization weights parameters

| Parameter | Value |
|---|---|
| Maximize Flexibility: | Very Important / Important / Fairly Important / Less Important / Not Important |
| Minimize Complexity: | Very Important / Important / Fairly Important / Less Important / Not Important |
| Maximize Sustainability: | Very Important / Important / Fairly Important / Less Important / Not Important |
| Maximize Optimum Use of Resources: | Very Important / Important / Fairly Important / Less Important / Not Important |
| Minimize Risk: | Very Important / Important / Fairly Important / Less Important / Not Important |

# APPENDIX F

## Evaluation of a COA

This appendix describes the procedure to evaluate a COA.

The final evaluation score of a COA option is obtained from a summation of its weighted scores on the five evaluation factors:

$$EVAL = W_{flex} \cdot FLEX + W_{cmpx} \cdot CMPX + W_{sustn} \cdot SUSTN + W_{optm} \cdot OPTM + W_{risk} \cdot RISK$$

where:

EVAL - Final Evaluation Score
FLEX - Flexibility Evaluation Score
CMPX - Complexity Evaluation Score
SUST - Sustainability Evaluation Score
OPTM - Optimality (Optimum Use of Resources) Evaluation Score
RISK - Risk Evaluation Score
$W_{flex}$ - Weight for Flexibility Evaluation Score
$W_{cmp}$ - Weight for Complexity Evaluation Score
$W_{sust}$ - Weight for Sustainability Evaluation Score
$W_{opt}$ - Weight for Optimality Evaluation Score
$W_{risk}$ - Weight for Risk Evaluation Score

### F.1 Flexibility Evaluation

The flexibility evaluation score of a COA option is obtained from a normalized summation of its weighted scores on the nine subfactors:

$$WEIGHT\text{-}SUM_{flex} = W_{nso} + W_{nmo} + W_{co} + W_{oo} + W_{ot} + W_{tl} + W_{ecoa} + W_{edcp} + W_{ra}$$

$$FLEX = (1 / WEIGHT\text{-}SUM_{flex}) \cdot (W_{nso} \cdot NSO + W_{nmo} \cdot NMO + W_{co} \cdot CO + W_{oo} \cdot OO + W_{ot} \cdot OT + W_{tl} \cdot TL + W_{ecoa} \cdot ECOA + W_{edcp} \cdot EDCP + W_{ra} \cdot RA)$$

where:

NSO - National Security Objectives Change Flexibility Evaluation Score
NMO - National Military Objectives Change Flexibility Evaluation Score
CO - Campaign Objectives Change Flexibility Evaluation Score
OO - Operational Objectives Change Flexibility Evaluation Score

OT - Operational Tasks Change Flexibility Evaluation Score
TL - Mission's Time and Location Change Flexibility Evaluation Score
ECOA - Enemy's Course Of Action Change Flexibility Evaluation Score
EDCP - Enemy's Deception Change Flexibility Evaluation Score
RA - Resource Availability Change Flexibility Evaluation Score
$W_{nso}$ - Weight for the National Security Objectives Change Flexibility Evaluation Score
$W_{nmo}$ - Weight for the National Military Objectives Change Flexibility Evaluation Score
$W_{co}$ - Weight for the Campaign Objectives Change Flexibility Evaluation Score
$W_{oo}$ - Weight for the Operational Objectives Change Flexibility Evaluation Score
$W_{ot}$ - Weight for the Operational Tasks Change Flexibility Evaluation Score
$W_{tl}$ - Weight for the Mission's Time and Location Change Flexibility Evaluation Score
$W_{ecoa}$ - Weight for the Enemy's Course Of Action Change Flexibility Evaluation Score
$W_{edcp}$ - Weight for the Enemy's Deception Change Flexibility Evaluation Score
$W_{ra}$ - Weight for the Resource Availability Change Flexibility Evaluation Score

The list of possible values for the first five changes (NSO, NMO, CO, OO and OT) is given in Table IV of Appendix C.

### F.1.1 National Security Objectives Change Flexibility Evaluation

The computation for the National Security Objective Change Flexibility Evaluation is a process that examines which and how many national security objectives specified in the event condition are covered by those specified in the COA option feature. It then calculates the percentage of desired objectives covered by the COA:

NSO = Num_NSO_Cvrd / Num_NSO_Prsd

where

Num_NSO_Cvrd - Total Number of National Security Objectives Covered by COA Option Feature
Num_NSO_Prsd - Total Number of National Security Objectives Pursued in Event Conditions

### F.1.2 National Military Objectives Change Flexibility Evaluation

The computation for the National Military Objective Change Flexibility Evaluation is a process that examines which and how many national military objectives specified in the event condition are covered by those specified in the COA option feature. It then calculates the percentage of desired objectives covered by the COA:

NMO = Num_NMO_Cvrd / Num_NMO_Prsd

where

| | | |
|---|---|---|
| Num_NMO_Cvrd | - | Total Number of National Military Objectives Covered by COA Option Feature |
| Num_NMO_Prsd | - | Total Number of National Military Objectives Pursued in Event Conditions |

### F.1.3 Campaign Objectives Change Flexibility Evaluation

The computation for the Campaign Objective Change Flexibility Evaluation is a process that examines which and how many campaign objectives specified in the event condition are covered by those specified in the COA option feature. It then calculates the percentage of desired objectives covered by the COA:

CO = Num_CO_Cvrd / Num_CO_Prsd

where

| | | |
|---|---|---|
| Num_CO_Cvrd | - | Total Number of Campaign Objectives Covered by COA Option Feature |
| Num_CO_Prsd | - | Total Number of Campaign Objectives Pursued in Event Conditions |

### F.1.4 Operational Objectives Change Flexibility Evaluation

The computation for the Operational Objective Change Flexibility Evaluation is a process that examines which and how many operational objectives specified in the event condition are covered by those specified in the COA option feature. It then calculates the percentage of desired objectives covered by the COA:

OO = Num_OO_Cvrd / Num_OO_Prsd

where

| | | |
|---|---|---|
| Num_OO_Cvrd | - | Total Number of Operational Objectives Covered by COA Option Feature |
| Num_OO_Prsd | - | Total Number of Operational Objectives Pursued in Event Conditions |

### F.1.5 Operational Tasks Change Flexibility Evaluation

The computation for the Operational Task Change Flexibility Evaluation is a process that examines that and how many operational tasks specified in the event condition are covered by those specified in the COA option feature. It then calculates the percentage of desired objectives covered by the COA:

OT = Num_OT_Cvrd / Num_OT_Prsd

where

| | | |
|---|---|---|
| Num_OT_Cvrd | - | Total Number of Operational Tasks Covered by COA Option Feature |
| Num_OT_Prsd | - | Total Number of Operational Tasks Pursued in Event Conditions |

### F.1.6 Mission's Time and Location Change Flexibility Evaluation

The computation for the Mission Time and Location Change Flexibility Evaluation is a process that examines which and how many mission locations specified in the event condition are covered by those specified in the To descriptor of action items of a COA option. It then calculates the percentage of locations covered by the COA:

TL = Num_TL_Cvrd / Num_TL_Spec

where

| | | |
|---|---|---|
| Num_TL_Cvrd | - | Total Number of Mission Locations Covered by COA Option |
| Num_TL_Spec | - | Total Number of Mission Locations specified in Event Conditions |

### F.1.7 Enemy's Course of Action Change Flexibility Evaluation

The computation for the Enemy's Course of Action Change Flexibility Evaluation is a process that first normalizes the certainty value for each possible enemy's course of action, i.e. distributes 100% among the enemy's courses of action proportionally to the assigned certainty value; then, it examines which enemy's courses of action specified in the event condition are covered by those specified in the COA option feature; finally, it computes the total coverage by summing up the normalized certainty values of all covered enemy's courses of action.

Let:

| | | |
|---|---|---|
| $ECOA_PDCT_i$ | - | Enemy's course of action option predicted, where i = 1, 2, . . . n. |
| $ECOA_CTNT_i$ | - | Certainty value for $ECOA_PDCT_i$ |
| TTL_ECOA_CTNT | - | Total of certainty values |
| $NORM_ECOA_CTNT_i$ | - | Normalized certainty value for $ECOA_PDCT_i$ |
| $ECOA_CVRD_j$ | - | Enemy's course of action option covered, where j = 1, 2, ..., m, and $m \leq n$. |

Thus:

1) $$TTL_ECOA_CTNT = ECOA_CTNT_1 + ECOA_CTNT_2 + \ldots + ECOA_CTNT_n$$

2) $$NORM_ECOA_CTNT_1 = ECOA_CTNT_1 / TTL_ECOA_CTNT$$
$$NORM_ECOA_CTNT_2 = ECOA_CTNT_2 / TTL_ECOA_CTNT$$
$$\vdots$$
$$NORM_ECOA_CTNT_n = ECOA_CTNT_n / TTL_ECOA_CTNT$$

3) For those $NORM_ECOA_CTNT_i$, where $ECOA_PDCT_i = ECOA_CVRD_j$, compute:

$$ECOA = \sum NORM_ECOA_CTNT_i$$

### F.1.8 Enemy's Deception Change Flexibility Evaluation

The computation for the Enemy's Deception Change Flexibility Evaluation is a process that first normalizes the certainty value for each possible enemy's deception, i.e. distributes 100% among the enemy courses of action proportionally to the assigned certainty value; then, it examines which enemy's deception specified in the event condition are covered by those specified in the COA option feature; finally, it computes the total coverage by summing up the normalized certainty values of all covered enemy's deceptions.

The above computational process is elaborated as follows:

Let:

| | | |
|---|---|---|
| $EDCP_PDCT_i$ | - | Enemy's deception option predicted, where $i = 1, 2, \ldots n$. |
| $EDCP_CTNT_i$ | - | Certainty value for $EDCP_PDCT_i$ |
| TTL_EDCP_CTNT | - | Total of certainty values |
| $NORM_EDCPT_CTNT_i$ | - | Normalized certainty value for $EDCP_PDCT_i$ |
| $EDCP_CVRD_j$ | - | Enemy's deception option covered, where $j = 1, 2, \ldots, m$, and $m \leq n$. |

Thus:

1) $TTL_EDCP_CTNT = EDCP_CTNT_1 + EDCP_CTNT_2 + \ldots + EDCP_CTNT_n$

2) $NORM_EDCP_CTNT_1 = EDCP_CTNT_1 / TTL_EDCP_CTNT$
$NORM_EDCP_CTNT_2 = EDCP_CTNT_2 / TTL_EDCP_CTNT$
$\vdots$
$NORM_EDCP_CTNT_n = EDCP_CTNT_n / TTL_EDCP_CTNT$

3) For those $NORM_EDCP_CTNT_i$, where $EDCP_PDCT_i = EDCP_CVRD_j$, compute:

$$EDCP = \sum NORM_EDCP_CTNT_i$$

### F.1.9 Resource Availability Change Flexibility Evaluation

The computation for the Resource Availability Change Flexibility Evaluation is a process that examines which and how many action items of a COA option have the alternatives. It then calculates the percentage of actions covered by the COA having a back-up, counting the value "yes" as one and the value "no" as zero for that purpose:

$$TTL_ARA = ACT_ARA_1 + ACT_ARA_2 + \ldots + ACT_ARA_n$$

$$RA = TTL_ARA / TTL_ACT$$

where:

| | | |
|---|---|---|
| $ACT_ARA_i$ | - | ARA for Action Item i, where i = 1, 2, . . . n. |
| TTL_ACT | - | Total number of action items. |
| TTL_ARA | - | Total of ARA |

### F.2 Complexity Evaluation

The complexity evaluation score of a COA option is obtained from a normalized summation of its weighted scores on the four subfactors:

$$WEIGHT\text{-}SUM_{cmpx} = W_{ops} + W_{logs} + W_{c\&c} + W_{aoo}$$

$$CMPX = -(1 / WEIGHT\text{-}SUM_{cmpx}) \cdot (W_{ops} \cdot OPS + W_{logs} \cdot LOGS + W_{c\&c} \cdot C\&C + W_{aoo} \cdot AOO)$$

where

| | | |
|---|---|---|
| OPS | - | Operations Complexity Evaluation Score |
| LOGS | - | Logistics Complexity Evaluation Score |
| C&C | - | Command and Control Complexity Evaluation Score |
| AOO | - | AOO Characteristics Complexity Evaluation Score |
| $W_{ops}$ | - | Weight for the Operations Complexity Evaluation Score |
| $W_{logs}$ | - | Weight for the Logistics Complexity Evaluation Score |
| $W_{c\&c}$ | - | Weight for the Command and Control Complexity Evaluation Score |
| $W_{aoo}$ | - | Weight for the AOO Characteristics Complexity Evaluation Score |

Note the minus sign in the equation. It is because the CMPX is a negative factor which degrades the final evaluation score and thus the priority of a COA option.

### F.2.1 Operations Complexity Evaluation

The possible values for these three features are "high", "medium" and "low". The computation for the Operations Complexity Evaluation is a process that first fetches the values of the above three COA option features. weights the fetched values. It then computes a normalized summation over the weighted values, counting the value "high" as "1" (one), the value "medium" as "0,5" and the value "no" as "0" (zero) for that purpose:

$$OPS = [1 / (W_{qnt_eqp} + W_{qnt_func} + W_{func_diff})] \cdot (W_{qnt_eqp} \cdot QNT_EQP + W_{qnt_func} \cdot QNT_FUNC + W_{func_diff} \cdot FUNC_DIFF)$$

where:

| | | |
|---|---|---|
| QNT_EQP | - | Quantity of Equipment in Operations |
| QNT_FUNC | - | Quantity of Function in Operations |
| FUNC_DIFF | - | Function Difficulty |
| $W_{qnt_eqp}$ | - | Weight for QNT_EQP |
| $W_{qnt_func}$ | - | Weight for QNT_EQP |
| $W_{func_diff}$ | - | Weight for FUNC_DIFF |

### F.2.2 Logistics Complexity Evaluation

The computation for the Logistics Complexity Evaluation first fetches the values of the above five COA option features, weights the fetched values, and then computes a normalized summation over the weighted values, counting the value "high" as "1" (one), the value "medium" as "0,5" and the value "no" as "0" (zero) for that purpose:

$$LOGS = [1 / (W_{sch_logs} + W_{psn_logs} + W_{rfl_logs} + W_{ldn_logs} + W_{cmn_logs})] \cdot (W_{sch_logs} \cdot SCH_LOGS + W_{psn_logs} \cdot PSN_LOGS + W_{rfl_logs} \cdot RFL_LOGS + W_{ldn_logs} \cdot LDN_LOGS + W_{cmn_logs} \cdot CMN_LOGS)$$

where:

| | | |
|---|---|---|
| SCH_LOGS | - | Scheduling Logistics Requirements |
| PSN_LOGS | - | Personnel Logistics Requirements |
| RFL_LOGS | - | Refueling Logistics Requirements |
| LDN_LOGS | - | Landing Logistics Requirements |
| CMN_LOGS | - | Communication Logistics Requirements |
| $W_{sch_logs}$ | - | Weight for SCH_LOGS |
| $W_{psn_logs}$ | - | Weight for PSN_LOGS |
| $W_{rfl_logs}$ | - | Weight for RFL_LOGS |
| $W_{ldn_logs}$ | - | Weight for LDN_LOGS |
| $W_{cmn_logs}$ | - | Weight for CMN_LOGS |

### F.2.3 Command and Control Complexity Evaluation

The computation for the Command and Control Complexity Evaluation first fetches the values of the above two COA option features, weights the fetched values, and then computes a normalized summation over the weighted values, counting the values "multiple" and "combination" as "1" (one), the value "with other government agencies" as "0,75", the values "pair or shared" and "with police" as "0,5", the value "with other military forces" as "0,25" and the values "single" and "none" as "0" (zero) for that purpose:

$$C\&C = [1 / (W_{ccr} + W_{crd})] \cdot (W_{ccr} \cdot CCR + W_{crd} \cdot CRD)$$

where:

| | | |
|---|---|---|
| CCR | - | Command and Control Relationships |
| CRD | - | Coordination Requirements |
| $W_{ccr}$ | - | Weight for CCR |
| $W_{crd}$ | - | Weight for CRD |

### F.2.4 AOO Characteristics Complexity Evaluation

The computation for the AOO Characteristics Complexity Evaluation first fetches the values of the above AOO characteristics, weights the fetched values, and then computes a normalized summation over the weighted values, counting the values "red" and "multiple legs" as "1" (one), the value "two legs" as "0,67", the value "yellow" as "0,5", the value "one leg" as "0,33" and the values "green" and "no refueling requirement" as "0" (zero) for that purpose:

$$AOO = [1 / (W_{wth_aoo} + W_{afa_aoo} + W_{dst_aoo})] \cdot (W_{wth_aoo} \cdot WTH_AOO + W_{afa_aoo} \cdot AFA_AOO + W_{dst_aoo} \cdot DST_AOO)$$

where:

| | | |
|---|---|---|
| WTH_AOO | - | Weather Condition in AOO |
| AFA_AOO | - | Air Field Availability in AOO |
| DST_AOO | - | Distance from AOO |
| $W_{wth_aoo}$ | - | Weight for WTH_AOO |
| $W_{afa_aoo}$ | - | Weight for AFA_AOO |
| $W_{dst_aoo}$ | - | Weight for DST_AOO |

**F.3 Sustainability Evaluation**

The computation for the sustainability evaluation first fetches the above data, then computes a maximum on-station time that may be required, finally determines the sustainability depending on whether the COA option feature "On-Station Time" is longer than the maximum possibly required on-station time.

The computational process for the sustainability evaluation is elaborated as follows:

Let:

| | | |
|---|---|---|
| $ONSTN_{max}$ | - | Maximum Possibly Required On-Station Time |
| ONSTN | - | On-Station Time, |
| RQONSTN | - | Required On-Station Time, and |
| ADONSTN | - | Possible Additional Required On-Station Time. |

Thus:

$$ONSTN_{max} = RQONSTN + ADONSTN$$

$$SUSTN = 1, \text{ if } ONSTN >= ONSTN_{max}$$

or,

$$SUSTN = ONSTN / ONSTN_{max}, \text{ if } ONSTN < ONSTN_{max}$$

**F.4 Optimality Evaluation**

The possible values of the redundancy of resources are "lots", "some" and "none". The redundancy of resources is opposite to the optimality (optimum use of resources). Thus the computation for the optimality is to find the 1's complement of the redundancy of resources, counting the value "lots" as "1" (one), the value "some" as "0,5" and the value "none" as "0" (zero) for that purpose:

$$OPTM = 1 - RDNDNC$$

where:

RDNDNC - Redundancy of Resources

**F.5 Risk Evaluation**

The risk evaluation score of a COA option is obtained from a normalized summation of its weighted scores on the six subfactors:

$$WEIGHT\text{-}SUM_{risk} = W_{bt} + W_{sen} + W_{pl} + W_{cfn} + W_{ef}$$

$$RISK = -(1 / WEIGHT\text{-}SUM_{risk}) \cdot (W_{bt} \cdot BT + W_{sen} \cdot SEN + W_{pl} \cdot PL + W_{cfn} \cdot CFN + W_{ef} \cdot EF)$$

where:

| | | |
|---|---|---|
| BT | - | Bad Timing Risk Evaluation Score |
| SEN | - | Sensor Coverage Gap Risk Evaluation Score |
| PL | - | Personnel Loss Risk Evaluation Score |
| CFN | - | Confrontation Risk Evaluation Score |
| EF | - | Equipment Failure Risk Evaluation Score |
| $W_{bt}$ | - | Weight for the Bad Timing Risk in the risk evaluation, |
| $W_{sen}$ | - | Weight for the Sensor Coverage Gap Risk Evaluation Score |
| $W_{pl}$ | - | Weight for the Personnel Loss Risk Evaluation Score |
| $W_{cfn}$ | - | Weight for the Confrontation Risk Evaluation Score |
| $W_{ef}$ | - | Weight for the Equipment Failure Risk Evaluation Score |

Note the minus sign in the equation. It is because the RISK is a negative factor that degrades the final evaluation score and thus the priority of a COA option.

### F.5.1 Bad Timing Risk Evaluation

There exists an AIT ("Arrival In Time") descriptor in each action item of a COA option, which indicates whether the resources to be deployed as assigned in the action item can arrive in time. The values of the AIT have been chosen as Yes (= 1), Maybe (= 0.5) and No (= 0).

The computation for the Bad Timing Risk Evaluation is thus a process that first fetches the values of the AIT in each of action item, then converts these values to be the 1's complement of the AIT, finally computes an average value which represents the bad timing risk occurring possibility over all existing action items:

$$TTL_IND_BT = (1 - ACT_AIT_1) + (1 - ACT_AIT_2) + ... + (1 - ACT_AIT_n)$$

$$BT = TTL_IND_BT / TTL_ACT$$

where:

| | | |
|---|---|---|
| TTL_IND_BT | - | Total of individual bad timing risks. |
| $ACT_AIT_i$ | - | AIT for Action Item i, where i = 1, 2, ... n. |
| TTL_ACT | - | Total number of action items. |

### F.5.2 Sensor Coverage Gap Risk Evaluation

The possible values for these two features are "very large", "large", "medium", "small" and "none". The computation for the Sensor Coverage Gap Risk Evaluation first fetches the values of the above COA option features, weights the fetched values, and then computes a normalized summation over the weighted values, counting the value "very large" as "1" (one), the value "large" as "0,75", the value "medium" as "0,5", the value "small" as "0,25" and the value "none" as "0" (zero) for that purpose:

$$SEN = [1 / (W_{rdar} + W_{rdio})] \bullet (W_{rdar} \bullet RDAR_GAP + W_{rdio} \bullet RDIO_GAP)$$

where:

| | | |
|---|---|---|
| RDAR_GAP | - | Radar Gap |
| RDIO_GAP | - | Radio Gap |
| $W_{rdar}$ | - | Weight for RDAR_GAP |
| $W_{rdio}$ | - | Weight for RDIO_GAP |

### F.5.3 Personnel Loss Risk Evaluation

The possible values are "unsafe", "maybe" and "very safe". The Personnel Loss Risk Evaluation Score is determined by the value of the COA option feature "Personnel Safety", counting the value "unsafe" as "1" (one), the value "maybe" as "0,5" and the value "very safe" as "0" (zero) for that purpose:

$$PL = PS$$

where PS stands for the COA option feature "Personnel Safety".

### F.5.4 Confrontation Risk Evaluation

The possible values are "missile", "gun" and "none". The Confrontation Risk Evaluation Score is determined by the value of the COA option feature "Enemy's Weapon Capability", counting the value "missile" as "1" (one), the value "gun" as "0,5" and the value "none" as "0" (zero) for that purpose:

$$CFN = WPN$$

where WPN stands for the Enemy's Weapon Capability.

### F.5.5 Equipment Failure Risk Evaluation

The equipment failure risk evaluation score of a COA option is obtained from a normalized summation of its weighted scores on the two subfactors:

$$WEIGHT\text{-}SUM_{equ_fail_risk} = W_{to_ef} + W_{if_ef}$$

$$EF = (1 / WEIGHT\text{-}SUM_{equ_fail_risk}) \cdot (W_{to_ef} \cdot TOEF + W_{sIF_ef} \cdot IFEF)$$

where:

| | | |
|---|---|---|
| TOEF | - | Take-Off Equipment Failure Risk Evaluation Score |
| IFEF | - | In-Flight Equipment Risk Evaluation Score |

| | | |
|---|---|---|
| $W_{to_ef}$ | - | Weight for the Take-Off Equipment Failure Risk in the equipment failure risk evaluation, |
| $W_{if_ef}$ | - | Weight for the In-Flight Equipment Failure Risk in the equipment failure risk evaluation |

### F.5.5.1 Take-Off Equipment Failure Risk Evaluation

Definition: The Take-Off Equipment Failure Risk is concerned with the possibility of mission failure caused by mechanical failure of equipment before or at take-off.

As indicated earlier, a descriptor ARA (Alternate Resource Availability) is included in the description for each action item, which indicates if any alternatives exist for the resources assigned. Whether a equipment failure before or at take-off would cause the failure of a mission depends on the availability of another equivalent resource. The take-off equipment failure risk is opposite to the ARA. The possible values for the ARA have been defined as Yes (=1), Maybe (= 0.5) and No (=0).

The computation for the Take-Off Equipment Failure Risk Evaluation is thus a process that first fetches the values of the ARA for each action item, then converts them to be the 1's complement of the ARA, and finally computes an average value which represents the possibility of mission failure caused by mechanical failure of equipments used over all existing action items:

$$TTL_IND_TO_EF = (1 - ACT_ARA_1) + (1 - ACT_ARA_2) + \ldots + (1 - ACT_ARA_n)$$

$$TOEF = TTL_IND_TO_EF / TTL_ACT$$

where:

| | | |
|---|---|---|
| $ACT_ARA_i$ | - | ARA for Action Item i, where i = 1, 2, . . . n. |
| TTL_ACT | - | Total number of action items. |
| TTL_IND_TO_EF | - | Total of individual take-off equipment failure risks |

### F.5.5.2 In-Flight Equipment Failure Risk Evaluation

Definition: The In-Flight Equipment Failure Risk is concerned with the possibility of mission failure caused by mechanical failure of equipment during the flight of the resource.

The following equipment failure characteristics data are examined during the evaluation for in-flight equipment failure risk:

- On-Station Time
- Distance from Area of Operations
- Accident Rate of the equipment (in hours between accidents)
- Quantity of Equipment in Operations
- Additional Resource above SOP allocation

All these elements are COA Features and each has a value for each course of action

The computation for the Equipment Failure Risk Evaluation first fetches the values of the above five COA option features and then, counting the values in minutes and in accidents per 100 000 as is, and counting the value "multiple legs" as "6" (hours), the value "two legs" as "4.5" (hours), the value "one leg" as "3" (hours), the value "no refueling requirement" as "1.5" (hour), the values "high" and "yes" as "1" (one), the value "medium" as "0.5" and the values "low" and "no" as "0" (zero) for that purpose, apply the following formula:

$$IFEF = ( [(ONSTN / 60) + (2 * DST_AOO)] / AR ) * (2 + QEO - ARSOP)$$

where:

| | | |
|---|---|---|
| ONSTN | - | On-Station Time |
| DST_AOO | - | Distance from Area of Operations |
| AR | - | Accident Rate of the equipment (in hours between accidents) |
| QEO | - | Quantity of Equipment in Operations |
| ARSOP | - | Additional Resource above SOP allocation |

The value for the On-Station Time is a positive integer in minutes. The possible values for Distance from Area of Operations are "multiple legs", "two legs", "one leg" and "no refueling requirement". The value for the Accident Rate is the avarage number of hours between two accidents. The possible values for the Quantity of Equipment are

"high", "medium" and "low". The possible values for the Additional Resource above SOP allocation are "yes" and "no".

**INTERNAL DISTRIBUTION**

**DREV TM-9739**

1 - Deputy Director General

1 - Chief Scientist

6 - Documents Library

1 - Decision Aid Technologies Section Head

1 - Dr. I. Abi-Zeid (author)

1 - Mrs. M. Bélanger (author)

1 - Mr. J. Berger

1 - Mr. L. Lamontagne

1 - Dr. É. Bossé

1 - Maj. F. Beaupré

1 - Mr. V. Pille

**EXTERNAL DISTRIBUTION**

**DREV TM-9739**

1 - DRDIM

1 - DRDIM (unbound copy)

1 - DRDB

1 - Air Command Headquarters
Westwin MB R3J 0T0
Attn: Charles Hunter
DCOS Ops Research

1 - Dr. J.-M. Martel (author)
Université Laval
Département des opérations et systèmes de décision
Faculté des sciences de l'administration
Québec, Canada, G1K 7P4

1 - Mr. A. Guitouni (author)
Université Laval
Département des opérations et systèmes de décision
Faculté des sciences de l'administration
Québec, Canada, G1K 7P4

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

## DOCUMENT CONTROL DATA

1. ORIGINATOR (name and address)

DREV
2459 Blvd Pie XI North
Val-Bélair, Qc
G3J 1X5

2. SECURITY CLASSIFICATION
(Including special warning terms if applicable)

UNCLASSIFIED

3. TITLE (its classification should be indicated by the appropriate abbreviation (S,C,R or U)

The Reformulation of the family of criteria inCommander's Expert System Advisor (CESA) (U)

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

Abi-Zeid, I., Bélanger, M., Guitouni, A.*, Martel, J.-M.* (*Université Laval)

| 5. DATE OF PUBLICATION (month and year) | 6a. NO. OF PAGES | 6b. NO. OF REFERENCES |
|---|---|---|
| June 1998 | 100 | 2 |

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. Give the inclusive dates when a specific reporting period is covered.)

Memorandum

8. SPONSORING ACTIVITY (name and address)

DREV

| 9a. PROJECT OR GRANT NO. (Please specify whether project or grant) | 9b. CONTRACT NO. |
|---|---|
| 3aa12 | |

| 10a. ORIGINATOR'S DOCUMENT NUMBER | 10b. OTHER DOCUMENT NOS. |
|---|---|
| DREV TM-9739 | N/A |

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

- [X] Unlimited distribution
- [ ] Contractors in appoved countries (specify)
- [ ] Canadian contractors (with need-to-know)
- [ ] Government (with need-to-know)
- [ ] Defence departments
- [ ] Other (please specify) :

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

13. ABSTRACT ( a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

This memorandum presents a brief description of the current state of an advisor tool developed at DREV for the Air Commander, called Commander's Expert System Advisor (CESA). CESA takes a list of courses of actions (COAs) constructed in response to an event, evaluates them with respect to certain factors and subfactors, obtains a ranking of these COAs using priorities given by the Commander, and then recommends a COA.

The main goal of this work is to report the results of a research project which redefined the factors and subfactors in CESA as 14 criteria in a multicriteria decision aid context. Many subfactors were eliminated, and new scales for evaluating the COAs were developed. This reformulation of the criteria is specific to events that correspond to the violation of Canadian airspace in a counterdrug scenario in a peace time normal context.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each could be indicated as with the title.)

Multicriteria
CESA
Coherent Family
Evaluation Scales